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# **Making Sustainable and Environmental Improvements Through Focused Factories**

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For:

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Winter 2005 - 2006

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**CERTIFICATE OF APPROVAL**

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MASTER OF SCIENCE DEGREE

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The M.S. Thesis of Kyle Hurst  
has been examined and approved  
by the thesis committee as satisfactory  
for the thesis requirements for the  
Master of Science Degree

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# 1. Abstract

The purpose of this thesis is to examine the relationship between environmental strategy, business strategy, and manufacturing strategy. Specifically, this paper evaluates the potential link between a manufacturing strategy known as focused manufacturing (focused factories) and improved environmental performance. The thesis explores the current literature on focused factories and various environmental tools and strategies. Barriers to sustainable and environmental improvements are discussed, as well as the integration of environmental strategy into the overall business strategy of a company. To examine the relationship between focused factories and environmental improvement, statistical analysis is performed on data generated from a web-based survey sent to various manufacturing companies in the western NY area. The survey consisted of 39 questions, designed to measure 1) the level of focus for each respondent, and 2) environmental performance pertaining to three specific hypotheses created for this experiment. The creation, validation, and analysis of the survey and corresponding hypotheses are discussed in detail. The analysis showed positive correlation between focused manufacturing and increased cost savings and earning potential due to environmental efforts, the inclusion of environmental goals and priorities into the overall business strategy, and bringing environmental considerations into the early stages of product development. Focus was also positively correlated to greater employee involvement and awareness of environmental issues. The thesis is an initial exploration into the relationships between environmental strategy, business strategy, and manufacturing strategy. Recommendations for future projects of this nature are made.

## 2. Introduction

It seems like more companies should be interested in environmental improvement. Through environmental improvements, companies can increase their profits by reducing material use, reducing energy consumption, improving a firm's image, etc. However, many companies view environmental improvements as a nagging burden to their time, resources, and profits. Are companies making smart decisions when it comes to environmental development? Do companies truly realize the strategic nature of environmental improvements? It is likely that without establishing a clear business strategy that includes sustainable and environmental goals, there is little hope that a company will ever successfully see significant environmental improvements.

Environmental improvements require careful thought and analysis into many different areas including product design, manufacturing, marketing, engineering, logistics, etc. It is probably not often clear to a company what specific actions will give them the most environmental success. Also, the bureaucratic nature of business likely slows environmental improvements. Most companies are unable to develop the appropriate infrastructure resources to successfully implement significant environmental and sustainable improvements (Charter, 2001).

Looking at these barriers, it's possible that companies that can better manage their internal and external complexity should have a greater ability to correctly identify and make environmental improvements. In essence, companies that are more organized and well run should be better able to pinpoint areas of environmental improvement, and have more effective infrastructures in place to develop and implement appropriate environmental solutions.

One method for better managing a company is Focused Manufacturing. Focus manufacturing is a method for organizing and aligning a company's resources with its overall business strategy. It is a method of simplifying so that companies will concentrate their efforts on those things they do well. It is a method of making factories more manageable by structuring basic manufacturing policies and supporting services so that they focus on a limited and consistent set of manufacturing tasks, instead of many inconsistent, conflicting tasks.

If focus factories can help to properly align and organize a business then, theoretically, focus factories should be an ideal basis for making more appropriate environmental improvements. Perhaps being focused is closely linked to being green.



### **3. Problem Statement / Scope of Work**

There is continual talk in industry about the need for environmental and sustainable improvement, yet there seems to be little change in practice. This paper examines the organizational issues that hinder environmental and sustainable development, and show how these issues relate to the concept of focused manufacturing. The accompanying research and survey examine the correlation between focused factories and environmental improvements. The results may help companies understand the issues associated with environmental and sustainable development, and how these issues are connected to competitive business strategy, manufacturing strategy, and infrastructure. Ideally, this paper will serve as a guideline to help steer companies in the right direction towards effective environmental progress.

The scope of work for this thesis includes four general parts: The first section includes research and discussion of the current literature surrounding focused factories and environmental and sustainable design and development, and how they both relate to competitive business strategy. The research will also examine several barriers to environmental and sustainable design and development.

The second segment consists of the development of theories that present linkages between “focus” and improved environmental performance. That is, cases are presented that show how focused factories may correlate with more effective environmental activity.

The next segment of the thesis is the development, validation, and administration of a business survey consisting of several questions pertaining to plant focus and environmental performance. The survey was sent out to various manufacturing plants in the western New York area.

The final portion of the thesis involves collecting the raw data from the survey, statistically analyzing it, discussing the results, and making final conclusions. The survey analysis consists of assigning of “degree of focus” for each plant based on their answers for a particular set of questions, and then measuring their corresponding environmental performance based on another set of select questions. Statistical analysis is performed to determine the amount of correlation between the focus and environmental performance.

## **4. Literature Review**

### **4.1 Focused Factories**

#### **4.1.1 Why Focus? The theory behind focused factories.**

The theory for focused factories (or focused manufacturing) was first introduced by Wickham Skinner in the 1970's, at a time when the economy was facing the pressures of advancing technologies and shorter product lives. Skinner believed that companies guided by the principles of economies of scale often attempt to do too many things with one plant (1974). He argued that a plant cannot do a large variety of very different tasks exceptionally well, and a plant can achieve superior performance by concentrating its resources on accomplishing a limited set of tasks, rather than trying to meet an endless series of demands from internal and external sources (1974).

Skinner also illustrated how top management had failed to recognize the strategic importance of manufacturing and how differing marketing requirements force plants to chase conflicting objectives. According to Skinner, "what is not always realized is that different marketing strategies and approaches to gaining a competitive advantage place different demands on the manufacturing arm of the company" (1969, p. 137).

Skinner (1974) formally recognized the concept of focus and the potential benefits of focusing the manufacturing organization. He proposed focused manufacturing as a new management approach that can help companies manage the manufacturing requirements created by a broad mix of products, volumes, specifications, and customer demand patterns (1974). He based his beliefs on the idea that various competitive priorities (such as quality, delivery, flexibility and cost) imply trade-offs, and that simplicity, repetition, experience, and homogeneity breed competence (1974). Skinner argues that firms should learn to focus each plant on a limited set of products, technologies, and markets. In addition, manufacturing managers must design the plant, processes and infrastructure to focus on an explicit manufacturing task defined by the manufacturing strategy. Thus, each focus factory is assigned a unique set of manufacturing tasks derived from the firm's competitive strategy. Such a design helps management to reduce complexity and achieve consistency in a manufacturing system. According to Skinner, the focused plant "can become a competitive weapon because its

entire apparatus is focused to accomplish the particular manufacturing task demanded by the company's overall strategy and marketing objective" (1974, p. 114).

In 1989, Terence Hill emphasized the importance of focused manufacturing strategy in business. Hill recognized the inherent complexity of manufacturing that stemmed from such things as the number of issues involved in the task, the interrelated nature of these tasks (i.e., time dependency, scheduling, logistics), and the level of fit between the manufacturing strategy, the internal process capability, and the infrastructure. Hill believed managing this complexity was a key corporate role, and began by developing a sound corporate strategy that is "not based solely on marketing, manufacturing or any other function, but one that embraces the interface between markets and functions" (1989, p. 26). Hill believes companies need to properly link each of their functional departments with the markets the business serves or intends to serve. Hill states, "being competitive in different types of markets is a prerequisite for a company today and the concept of focus offers the principles to achieve this" (1989, p. 148).

Shue and Laughlin (1996) stress the advantages of integrating marketing and manufacturing through focus design. According to them, marketing management is often faced with the nearly impossible task of handling a large variety of customer demands (1996). At the same time, another difficult task in manufacturing management is responding to the variety of marketing requirements placed on a single task (1996). Therefore, both manufacturing and marketing management are struggling with the same problem from different perspectives. Recognizing that the strategic problems of both manufacturing and marketing are attributable to diverse customer requirements offer the potential for a common solution to those problems (1996). A plant can become non-competitive if its policies are not focused on the key manufacturing tasks essential to compete successfully in each of its various markets. Therefore, Shue argues it is important that plant management designs a manufacturing system which simultaneously meets diverse market requirements and still maintains its competitiveness (1996). Shue believes the focus approach is the best method to achieve this.

Several other researchers support the need for focus. When determining the different competitive priorities on which a company can compete, Hayes and Wheelwright point out that "it is difficult to offer superior performance along all of these

dimensions simultaneously, since it will only be second best to some other company that devotes more of its resources to developing that competitive advantage” (1984, p.41). Hayes and Wheelwright created what is known as the Product/Process Matrix to directly address the relationship between product life cycles and the production process (1979). The Product/Process Matrix helps to underline the idea that key elements of the manufacturing process must be internally consistent, as well as consistent with a firm's product requirements (Hayes and Wheelwright, 1979). Hayes and Wheelwright argue that since product types often evolve from low-volume, custom products to high volume, standardized ones, the process used to make them must also evolve over time (1979).

Works by Hill and Duke-Woolley (1983) and Schmenner (1983) emphasize the effect of gradual, uncontrolled product proliferation on the manufacturing organization. They argue that as companies grow and attempt to produce a larger range of products, this widening product portfolio creates a widening variety of product needs that forces the manufacturing elements of that organization to become internally inconsistent over time. The result is a manufacturing organization that cannot do anything particularly well. Schmenner states: “Product proliferation is a sure way to sap a plant's competitive juices. The plant becomes more crowded; inventory of all types builds up along with the racks and enclosures to store it; production planning and control systems necessarily become more complicated, more ponderous, and more prone to error; machine uptime declines and changeovers abound; and the workforce continually worries that it is losing the battle” (1983, p.123).

Hill and Duke-Woolley describe this phenomenon as "focus regression." The authors point out that differences in competitive priorities for a set of products (such as quality level, delivery speed, or cost) can severely impair plant performance, even if the physical manufacturing processes are the same (1983). They describe focus as being "based on the concept that there needs to be a set of tasks in the key areas of manufacturing which are consistent with one another and are also consistent within the manufacturing strategy necessary to support the corporate marketing requirement" (1983, p.114). Bozarth points out that this definition reflects the importance not only of internal consistency within the manufacturing operation but also of linking marketing requirements to manufacturing capabilities (1993).

#### **4.1.2 Defining Focus: What exactly is it?**

Although it is relatively a simple concept, the definition of focus is not clearly understood by many managers and executives. Its non-specific nature can cause it to be interpreted differently among different people. Focus is more subtle than it might first appear. It is difficult to define, difficult to implement, and difficult to maintain over the long run (Pesch and Schroeder, 1994).

Often the word “narrowing” is used to explain focus. This stems from Skinner’s argument that “a plant that focuses on a narrow product mix for a particular market niche will outperform the conventional plant which attempts a broader mission” (1974, p.114). However, this statement can be misleading. Many companies must have diverse product portfolios to satisfy different market segments and demands. Hill argues that markets based on different criteria will only present conflicting requirements for manufacturing if facilities are not organized to meet these differences (1989). Focus should therefore be viewed as “splitting the whole into parts” rather than “narrowing”. Making better use of large key resources is the aim. Pesch and Schroeder add, “A focused plant can have a large number of products if they belong to the same family and consist of options and features that do not place different demands on manufacturing” (1994, p.77).

Skinner has more recently tried to clarify his original focus concept by stating that focused plants need not be necessarily product focused or even “simple or small” (1996). He emphasizes that a focused factory is “the factory or productive unit of a manufacturing system in which policies and structure are the result of a management process that focuses the entire set of manufacturing policies around a clearly expressed manufacturing task. This has nothing to do with size; it has everything to do with the design of the system. Focus is a state of mind and focusing is the management process of designing a coherent structure to accomplish a strategic task” (1996, p.8).

Hill believes focused manufacturing concerns better fitting the manufacturing strategic task, the internal process capability, and the infrastructure to the appropriate competitive factors of its business with the aim of enabling that company to gain a greater control of its competitive position (1989). Being able to align manufacturing facilities and supporting activities to the particular needs of various markets enables companies to compete effectively. He defines focus as “arranging each plant on a limited

set of products, technologies, volumes, and markets” (1989, p. 142). This means that basic manufacturing policies and supporting services should be structured so they focus on a limited and consistent set of manufacturing tasks, instead of on many inconsistent, conflicting tasks.

A key component is linking the various components of a factory to a well-defined, specific business strategy. Pesch and Schroeder define a focused factory as one with “a limited and consistent set of demands that originate from its products, processes, and customers, enabling the factory to effectively support the business strategy” (1994, p. 77).

Bozarth analyzed most of the existing research on focused factories and determined that the research stressed three common themes (1993):

1. Elements of the manufacturing organization must be internally consistent in order for manufacturing to function effectively.
2. Elements of the manufacturing organization must also match the business strategy or product requirements of the firm.
3. Diversity within product requirements will lead to internal inconsistency among the manufacturing elements.

From this observation, Bozarth recognized three distinct dimensions of focus (1993): The first dimension is called manufacturing characteristics focus, which captures the idea of internal consistency within the elements of the manufacturing organization. The second dimension of focus is called market requirements focus, which refers to the consistency of product demands put on an individual plant. The third dimension, market/manufacturing congruence, reflects the degree of fit between marketing requirements and manufacturing characteristics.

An expert panel based formal definition of the focused factory states (Pesch, 1996).

1. The focused factory is a factory with a limited, strategically linked, and internally consistent set of demands that derive from the plant’s products, processes, customers, and suppliers. Limiting the demands placed on the plant in turn limits the number of manufacturing tasks in the plant and establishes a clear set of priorities for both workers and managers.

2. Compatibility (versus numerical measures) of a plant's products, processes, and other plant characteristics is the critical issue in determining the degree of plant focus.
3. Plant focus is not an end in itself. The plant focus strategy must support and align with the business strategy. A plant can be inappropriately focused if plant departments and personnel are pursuing a strategy that conflicts with the business strategy.
4. Plants can be focused on flexibility, but a flexible plant that is truly focused has clear boundaries on the demands management strives to satisfy. A manager of a focused plant should be able to precisely identify what the plant does not do, in addition to what it does do.

#### **4.1.3 How to achieve focus.**

Hill believes the following steps are necessary to achieve focus: (1) process review, (2) identification of order-winners and qualifiers, (3) clustering products based on order-winners and qualifiers, (4) process rearrangement, (5) infrastructure rearrangement (1989). He emphasizes the importance of identifying order-winners and qualifiers as a way to understand the difference between markets. Order winners and qualifiers are basically another term for customer requirements or competitive priorities. These include such attributes as cost, quality, reliability, etc. Hill defines order-qualifiers as key criteria of a product that a company must meet for a customer to even consider it as a possible supplier. Order-winners are those criteria of superior performance that win orders by differentiating one firm from the others (1989). A summary of common order-winners and qualifiers is given in the Table 1:

**Table 1: Competitive Priorities (Shue and Laughlin, 1996)**

<u>Criterion</u>	<u>Definition</u>
1. Cost	Production and distribution of the product at lowest cost
2. Quality	(a) High performance: superior features, close tolerances, and great durability (b) Quality Consistency: the frequency of meeting design specifications
3. Delivery	(a) Dependability: the ability to meet delivery schedules or promises (b) Speed: the ability to react quickly to customer needs
4. Flexibility	(a) Product mix: the ability to react quickly to changes in types of products manufactured (b) Volume: the ability to react quickly to volume changes of a given product mix

There are five major ways to focus a plant (Hill,1989; Batista, 2000):

**1. Based on Product Lines/Markets**

This approach orients the relevant parts of the manufacturing facilities toward a particular customer (market segment) or a line of products. This is usually based on a marketing perspective (Hill, 1989). A major strength of this approach is that it can turn the development of a facilities strategy into a proactive process; creating and capitalizing on opportunities rather than simply reacting to the changing requirements for existing products and markets (Batista, 2000).

**2. Based on Processes**

This approach groups together products that are made with similar processes. The principal rationale is to gain advantages such as concentrated expertise and improved utilization of manufacturing processes (Batista, 2000).

**3. Based on Manufacturing's Strategic Task**

This approach allocates products to a particular focused unit on the basis of order-winners and order-qualifiers. This creates conditions where the manufacturing strategic task (i.e., what manufacturing has to do well to support the particular order-winners and qualifiers) is consistent (Hill, 1989). This approach can also be viewed as a benchmarking perspective, which offers an important dimension within the domain of order-winners by ensuring that corporate performance is measured against externally derived best practice norms (Batista, 2000).

**4. Based on volume**

This approach groups elements of manufacturing by the product demand. Volume is a useful criterion in defining manufacturing focus. Conflicting volume demands placed on different products in the same manufacturing system can cause such problems as machine setup conflicts, material movements, excess paperwork and transactions, un-coordination, and more work-in-process inventory, (Shue and Krawjewski, 1996). By separating the production of small jobs from large jobs, management achieves better productivity and administration improvements (Shue and Krawjewski, 1996).



## 5. Based on Life cycle

This approach defines focus by the products' positions in their life cycles. In order to prevent problems associated with focus regression, Schmenner suggests that firms should develop a plant focus strategy around the three phases of the plant's life cycle: the start-up and early years, the mature years, and the failing years (1983). Such a strategy could help managers avoid unrelated product diversification and over-expansion, and recognize when failing plants should be closed (1983).

Translating a set of manufacturing tasks into an appropriate plant organization is a critical aspect of focused manufacturing. However, it can not always be clear how to determine what type of focus is best for a particular company. What method of focus is necessary to best support the competitive priorities targeted by a particular market, and correspondingly how does a company arrange products and allocate resources into distinct focused units?

Unfortunately, there is no concrete, formal methodology to determine how to focus a plant. Researchers have different ideas on how to properly focus a plant. Fine and Hax (1985) identify plant focus by placing strategic product groups using Hayes and Wheelwright's product/process matrix. Berry *et al.* (1991) proposed an analytical approach in formulating plant focus by identifying the various requirements different markets placed on operations, and grouping products that had similar market requirements. Shue and Krawjewski (1996) developed a heuristic for formulating within-plant manufacturing focus using the similarity between products of 'competitive priorities' and 'volume' as surrogates for the set of manufacturing tasks.

Hill believes focusing around different order-winners and qualifiers wherever possible will yield the best results for arranging the factory and evaluating appropriate levels of infrastructure within the focused units (1989). This is because the manufacturing strategic task will be consistent. However, in reality, Hill suggests businesses are probably best served by adopting a combination of approaches. Companies need to be realistic and practical rather than dogmatic (1989).

Potential advantages and disadvantages to the alternative approaches are summarized in Table 2 (Hayes, Robert and Wheelwright, 1984, table 4-3):

**Table 2: Advantages and Disadvantages of Alternative Approaches to Focusing Facilities**

Advantages	Disadvantages
<b><i>Volume Split (high volume vs. low volume)</i></b>	
Exploits economies of scale, where appropriate	Duplication of production process, overhead, and inventories
Permits focusing on either cost effectiveness or production flexibility	Low volume plants can become orphans if not monitored carefully
Encourages customized development of production and management systems for products at different stages of their life cycle	
<b><i>Product / Market Split</i></b>	
Very responsive to market/customer needs and priorities	Duplication of resources across several facilities
Facilitates new product introduction	Product transfers become awkward
Permits specialization by market segment	Tendency to become unfocused as market shifts (high and low volume products produced in same plant)
Simplifies product cost estimation	Load imbalances develop as different markets grow at different rates
	Less emphasis on, and concentration of, technical skills in market-dominated environments
<b><i>Process Split</i></b>	
Concentrates technological expertise	Impedes radical changes in products or processes
Less duplication of equipment for producing common parts	Slows organization's response to totally new product/market requirements
Easier to balance loads among plants and keep utilization high	Longer cycle times and large pipeline inventories
Can develop customized process control systems	Higher cost of coordination
Encourages standardization	

#### **4.1.4 Rearranging the factory**

Focused manufacturing creates a structure in which each focused unit has its own facilities where it can concentrate on every element of the manufacturing task. Each part of the facility designs its own **processes** and **infrastructure**, which are arranged and developed in line with each focused task.

#### **4.1.4.1 Process rearrangement**

Once the products have been divided and grouped, and a criterion has been established for focusing, process rearrangement begins. Processes are allocated and physically moved to each corresponding focused unit.

Hill notes, “although the ideal plants would be individually focused to the needs of market and arranged on the basis of alternatives explained before, this is not often practical because of the sizable investments of many companies, and also because of the lack of focus generated when businesses change” (1989, p. 148).

Because of the sizable investments in new plants, equipment and tooling, a more practical approach may be the “plant-within-a-plant” (PWP) approach. In this case, the existing facilities are divided both organizationally and physically in to several PWP’s. Each of them can concentrate on its own particular manufacturing task, using its own workforce management approaches, production control, organizational structure, and so forth (Hill, 1989). This reduces units to a more manageable size, incorporating the advantages of both focus and smaller size.

#### **4.1.4.2 Infrastructure rearrangement**

Overheads are typically a very large part of an organization’s resources. Hill believes centralized specialists and typical overhead functions are often not aware of the distinct differences between various markets, nor the different manufacturing tasks required (1989). The demands on the process and support staff for products with different order-winners and qualifiers will most likely require different sets of processes and infrastructure. Orienting overheads to support the needs of a firm’s various markets will be a significant factor in the level of corporate success. Hill believes focus allows the company to make the most sizable improvements in infrastructure arrangements (1989).

A focused factory reshapes its overheads by allocating relevant support/specialist functions (in terms of both capability and capacity) to each focused unit. This brings forth a more decentralized infrastructure. The overhead resources must be physically allocated, that is, relevant staff must be located at the site, and not merely nominally designated to a central unit. Therefore responsibility for the management and direction of the staff involved clearly belongs to the focused unit (Hill, 1989).

By reallocating specialists and other staff members, where appropriate, to separate manufacturing units, a company can tailor support to the particular needs of each part of a business. This can lead to a significant reduction in overhead caused by unnecessary duplication of procedures and systems and unwanted provision of support staff (Hill, 1989).

Shue and Laughlin (1996) also discuss the revision of organizational responsibilities and authorities in a focused factory. They advocate that the adoption of a focus factory necessitates organizational changes throughout the firm, not just on the production side. Management must prepare for a new management style (1996). The primary objective of reorganization should be to re-establish the entrepreneurial management style in each PWP that is lost when becoming a big, bureaucratic organization (1996). Shue describes some of the organizational changes below:

- *Revised supervisory roles:* A focused factory will tend to need fewer supervisors, and the hours spent on traditional supervision and employee training are reduced. The reason for this is that the jobs and processes in a PWP are simplified dramatically. The simplicity not only reduces the training required but also eliminates most of the potential for making quality mistakes. The implication is that supervisors will have to shift their efforts towards process and product improvement (1996).
- *Unequal PWP size:* During this transition, firms often equate the physical organization of a factory with the supervisory and management organization, which results in a wide disparity in the number of people reporting to different supervisors or managers. It is likely that a small PWP could employ too few employees to warrant a full-time supervisor. Thus a supervisor might manage two small PWPs, or one small plus another large PWP (1996).
- *Indefinite PWP size:* Some practitioners advocate a minimum size of 30 employees while some Japanese companies accept 300 workers as the maximum number per PWP. This wide range suggests the difficulty in defining the nature of the supervisory organizational structure (1996).

In the traditional approach, functional departments usually make decisions and act according to their own objectives and points of view, without taking into account the needs of the other departments and the business as a whole. This leads to an uncoordinated infrastructure that fails to reach the level of effectiveness necessary to meet today's competitive pressures. Hill states, "The difference between an infrastructure

based on a number of specialist views and one coordinated to meet the needs of a business by an appropriate strategy is significant for most firms and critical for many” (1989 p. 174). Hill and Shue believe strategy should not be viewed as a process for allocating internal resources for organizational purposes, but instead involve positioning the firm with respect to the relationships between it and its customers, competitors and other factors in its environment. Seen in this fashion, the behavior of individual departments become complementary actions aimed at the firm’s objectives rather than conflicting actions aimed at departmental objectives (1989). The key to accomplishing this is the identification of objective measures, which supersede traditional departmental objectives and are accepted by all parties (1989).

Pesch and Schroeder (1994) believe focus goes beyond building a PWP. It requires cross-functional communications and involvement of all employees to ensure consistent decision-making. They argue that without fluid communication between manufacturing, product design, finance, marketing, and personnel, the demands placed on a plant can increase as each functional area pursues its own agenda (1994). Managers must pay as much attention to infrastructure in focusing their plants as they do to structure. They emphasize that proximity and communication among functional areas promote consistency in plant decisions (1994). They add, “For plant focus to be achieved and sustained, functional areas of the factory should be responsible for making decisions that support the overall plant strategy. Unless people in functional areas interact and communicate frequently with people in other functional areas, overall plant goals can easily be lost and replaced with departmental and individual goals that are more visible and immediate” (1994, p. 81).

They also believe that employee involvement is fundamental for focus success. Top management and plant managers should recognize the special contributions that direct labor employees can make to the plant focus effort. They point out, “because workers are responsible for much of the coordination that occurs in plants, they can facilitate focus by maintaining consistency of actions in the plant” (1994, p. 80). Direct labor can also bring to management’s attention inconsistent demands being placed on them by different products, processes, or customers, so management can take appropriate actions (1994). Involving direct labor can help maintain and improve plant focus.

#### **4.1.5 Advantages and disadvantages of focused factories.**

According to Hill, potential advantages of focused manufacturing include improved communication, greater orientation towards a well understood and agreed upon set of business objectives, more effective and efficient use of people, machines, and resources, simpler and more appropriate forms of control and managerial style, higher levels of employee participation and motivation, shorter process lead times, lower work-in-process inventory, reduced complexity of the production control task, and more accurate assessment of financial performance (1989).

Potential disadvantages include the fact that focused plants can run contrary to economies of scale and may well lead to the need to increase or duplicate certain processes or parts of the infrastructure such as procedures and specialist capabilities. However, Hill believes focusing provides the opportunity to better identify and correct any problems associated with each distinct manufacturing task. Judgments are much easier to make, owing to the improved clarity between business needs, direction, and overhead requirements (1989).

#### **4.1.6 Important issues involving focus**

Since Skinner's article in 1974, the concept of focus has been regarded as a part of good management practice. However, many issues should be considered before managers proceed with a focused factory strategy.

As previously mentioned, one confusing aspect of focus is the fact that it runs contrary to the widely accepted philosophy of economies of scale. Typical plants driven by these concepts often result in large facilities with process layouts based on functional similarity and centralized infrastructure. Conventional processes are often shared to facilitate higher levels of equipment utilization, and the firm's organization combines the line/executive function with appropriate specialists undertaking advisory and support roles (Hill, 1989).

A tradeoff caused by economies of scale is that while it helps reduce certain costs, it also causes other costs to increase. These costs are known as diseconomies of scale and include such things as (Hayes and Wheelwright, 1984):

- Diseconomies of distribution that result from shipments to a larger geographic area.
- Diseconomies of bureaucratization.
- Diseconomies of confusion that are caused by increases in the number of products, processes, and specialists in a given plant
- Diseconomies of vulnerability to risk.

Hill believes that although for many years economies of scale has been a sound and appropriate way of organizing and managing business, they can no longer be totally effective because “the markets and the necessary corporate response to support them have changed” (1989, p. 143). “While markets in the past were characterized by similarity, today’s markets are characterized by difference” (1989, p. 143). Economies of scale are most appropriate for high-volume and steady state markets, where most markets today are low-volume and dynamic in nature.

Hill points out that “marketing-led strategies are usually based on principles of growth through extending the product range by introducing new products on existing processes and within the infrastructure” (1989, p. 143). “Over time the incremental nature of these marketing changes will invariably alter the manufacturing task, causing complexity, confusion and a production organization that lacks focus” (1989, p. 143).

Hill also mentions the problems associated with improper machine utilization. He argues, “when capacity is released due to a falloff for a product, companies typically reutilize the spare capacity, supporting the argument of high plant utilization, by introducing new products. However, when evaluating the suitability of processes for a product, it is necessary for the companies to check not only that technical specifications are met, but the consistency of the business requirements over time, as products go through their life cycles and relevant order-winners accordingly change” (1989, p. 144).

Another important consideration is the realization that a high degree of focus is not always necessary for high profits. Focus is not an appropriate strategy for all facilities. Pesch mentioned a factory that produced a “hodgepodge” of over 2500 products, with many different processes and customers (1994). Yet the company was highly profitable and enjoyed high customer quality ratings and reliable deliveries. This

plant was successful because it mastered low volume, special order runs that were too small to attract large competitors. The company was very skilled at changing over their equipment quickly with minimal material waste.

Pesch adds, “the general purpose plant can be successful in certain circumstances, particularly when high levels of investment are a barrier to entry to the market and when work force competence can be developed and maintained quickly changing from one product to another. However, these cases are rare; in the large majority of plants, low focus leads to low profits” (1994, p. 79).

Hill believes focus should not be seen as the preferred dogma on which to base manufacturing arrangements. He states, “companies need to be pragmatic rather than dogmatic” and adds, “not all parts of the business can be successfully focused but the unfocused part will be smaller and easier to improve by other methods” (1989, p. 158-159).

Another confusing aspect of focused factories is that it seems to conflict with the concepts of flexible manufacturing systems (FMS), which exploits the gains from product proliferation and mass customization for economies of scope. Through computer integrated manufacturing (CIM) plants can achieve greater flexibility, better control and predictability of production processes, higher quality, faster product thru put lines, and reduced waste. It may seem that FMS may make focus less of a concern, as CIM provides the flexibility to produce a variety of products with varying production requirements. However, Pesch and Schroeder believe there are still very critical strategic implications in the decision to adopt flexible technologies. They state, “managers considering the purchase of flexible technology must understand the boundaries in which the plant will be flexible. Flexible equipment does not reduce the importance of focus. Instead, focus is necessary for determining the degree of flexibility that best fit the firms strategy” (1994, p. 79).

#### **4.1.7 Measuring the degree of focus.**

A frustrating aspect of focus is that even if it is achieved, it is very hard to measure. There is no clear-cut way of determining a “degree of focus” for a particular company. A



company can claim to be focused, but it is not clear how to tell if it actually is, or to compare its degree of focus to that of another company.

Skinner suggests, theoretically, a measure of manufacturing focus should include two dimensions: homogeneity and consistency (1979). Shue and Laughlin believe a measure of focus should evaluate both the matching of general corporate strategies and manufacturing tasks, and similarities of product characteristics within the same manufacturing unit. It could be a relative measure (e.g. a scale of zero to 100) or an absolute measure (e.g. standard deviation values of the operation variables such as production volume). Whatever it is, the development of such a measure is likely to involve subjective judgment as well as numerical data analysis (1996).

Few researchers have attempted to explicitly measure focus. A study by Pesch and Schroeder specifically looked at how to measure plant focus. The authors used "a literature-based degree of focus score (DFS)" derived from individual plants' scores on five criteria (1990). These criteria include:

- (1) Competitive priorities in plant should be limited to one.
- (2) The competitive priority in the plant must agree with the competitive priority for the business strategy.
- (3) Decisions in the plant must be internally consistent.
- (4) Product lines must have compatible volumes.
- (5) Manufacturing requirements must be similar among products.

Each criterion was scored on a 0-to-6-point scale, with 6 representing high focus. The DFS value for a given plant is the sum of the individual criterion scores, divided by the total possible score of 30 points and multiplied by 100. Pesch and Schroeder then use regression analysis to examine the relationships between the DFS measure for 24 plants-within-a-plant (12 different plant locations) and several environmental variables, including the number of product lines, the number of plant employees, plant age and process characteristics (1990).

Pesch and Schroeder determined that the results indicated that plants that produce a limited number of products and use continuous assembly processes are likely to be highly focused. Plants that produce multiple product lines, contain three or four processes, and rely heavily on batch and job shop processes are likely to have low focus (1994). Pesch and Schroeder (1996) discuss two advantages for this method of

measuring focus: (1) The approach allows each focus criterion to be analyzed individually for strengths and weakness in promoting plant focus. (2) Reducing the five focus criteria into a single value is useful for tracking the progress of focus efforts in the plant over time. They also point out their DFS score offers a key advantage for researchers who wish to quantify the focus construct and analyze focused factory relationships with quantitative techniques (1996). Pesch and Schroeder list traditional problems with survey methodology as weakness for their DFS measure including low response rates, a lack of control over how respondents interpret questionnaire items, someone other than the desired respondent filling out the questionnaire, and the overall uncertainty regarding accuracy in item responses (1996).

## **4.2. Sustainable/Environmental Design**

### **4.2.1 Why Bother?**

It is clear that the earth's natural reserves and ecosystems are under considerable pressure. Human activity has accelerated during the past 50 years to the point where it is impossible to ignore its global environmental impact. Consider that it took over 10,000 generations for the human population to reach 2 billion, but only a single lifetime to grow from 2 to over 5 billion (Gore, 1992). Human population will only continue to increase, and it is expected to double, to 10 billion, in the next 40 years (Keyfitz, 1989). To support this population growth, sources speculate it may be necessary to increase economic activity five- to tenfold (MacNeill, 1989). This level of economic production will most likely not be ecologically sustainable using existing technologies and production methods (Hart, 1995). A tenfold increase in resource use and waste generation would almost certainly stress the earth's natural systems beyond recovery (Schmidheiny, 1992).

Knowing this, industry will face increasing pressure to change its current unsustainable practices or face the possibility of irreversible damage to the planet's basic ecological systems. Many researchers predict that the basis for gaining competitive advantage in the coming years will be increasingly geared toward sustainable and environmental initiatives (Schmidheiny, 1992).

### **4.2.2 Basic Environmental/Sustainable principles**

**(Pollution control/prevention, DFE (eco-design), Sustainable Design, LCA, industrial ecology)**

The most fundamental, basic concept of environmental/sustainable activity is pollution and/or waste reduction/elimination. In a broad sense, there are essentially two approaches for dealing with pollution: control and prevention. Pollution control involves safely and effectively trapping, storing, treating, and disposing of harmful emissions and effluents in a manner that does not cause damage to the natural ecosystem (Hart, 1995). On the other hand, pollution prevention involves actual reduction or elimination of emissions, effluents and other wastes through product and process design changes (Hart, 1995). Prevention strategies are typically preferred over control strategies because they actually eliminate/reduce the existence of waste and emissions, whereas control strategies are viewed more as temporary "band-aids" that don't eliminate the problem. In addition,

pollution prevention strategies are much more likely to improve a company's financial performance. Through pollution prevention, companies produce less waste, which leads to reduced costs, increased productivity and efficiency, and better resource utilization (Hart & Ahuja, 1994; Romm, 1994; Schmidheiny, 1992; Young, 1991).

One of the most important components of environmental development is Design for the Environment (DfE). DfE, also known as Eco-Design, involves the integration of strategies for considering environmental aspects of products during the design process. The objective is to minimize the consumption of energy and natural resources through the product life cycle while maximizing value for customers. Eco-Design is based on the belief that if environmental aspects are taken into account during the earliest phases of product development, then it is more likely that lower environmental impacts can be 'built into' the final product (Tischner & Charter, 2001). Eco-Design has the potential to reduce costs, produce more innovative products and achieve more secure market positions than their less eco-sensitive competitors (Tischner & Charter, 2001).

## **Basic Eco-Design Practices:**

### **1. Design for Waste Elimination**

- Design for resource reduction
  - Reduce product dimensions
  - Specify lighter weight materials
  - Design thinner enclosures
  - Increase liquid concentration
  - Reduce mass of components
  - Reduce packaging weight
  - Use electronic documentation
- Design for easier separation of materials
  - Facilitate identification and sorting of materials
  - Use fewer types of materials
- Avoid material contaminants
- Design for waste incineration

### **2. Design for Material Conservation**

- Design multifunctional products
- Specify recycled materials
- Specify renewable materials
- Use remanufactured components
- Design for longevity
- Design for closed loop recycling

- Design for packaging recovery
- Design reusable containers

### **3. Design for Energy Conservation**

- Reduce energy use in production
- Reduce device power consumption
- Reduce energy use in transportation
  - Reduce distance traveled
  - Reduce transportation urgency
- Use renewable forms of energy

### **4. Design for Disassembly**

- Facilitate access to components
  - Optimize disassembly sequence
  - Design for easy removal
  - Avoid embedded parts
- Simplify component interfaces
  - Avoid springs, pulleys, harnesses
  - Avoid adhesives and welds
  - Avoid threaded fasteners
- Design for simplicity
  - Reduce number of parts
  - Design multifunctional parts
  - Use common parts

### **5. Design for Recovery and Reuse**

- Design for material recovery
  - Avoid composite materials
  - Specify recyclable material
  - Use recyclable packaging
- Design for component recovery
  - Design for reusable containers
  - Design for refurbishment
  - Design for remanufacturing

Many people view environmental and sustainable design/development as essentially the same thing. However, sustainable design/development goes further than solely making environmental improvements to a product or process. Sustainable development is defined by the WCED as ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ (Spangenberg, 2001). The basic theme of sustainability is to “maintain functioning systems in the long run to avoid irreversible damage, and to leave to future generations the choice of how they wish to use their heritage to provide the kind of quality of life they

prefer” (Spangenberg, 2001, p.30). This refers not only to the natural systems underlying industrial economies but also to social economic and institutional systems (Spangenberg, 2001).

Sustainable design goes beyond eco-design by attempting to integrate social and ethical aspects of product development, delivery and use along with environmental concerns. The “triple bottom line” objective is to improve economic performance, environmental performance and ethical performance of the parties involved. Sustainable design approaches help to:

- Decouple human “quality of life” issues from resource consumption
- Decouple corporate success from resource consumption
- Create more wealth while consuming considerably fewer resources
- Encourage “cradle to cradle” product responsibility (i.e. Remanufacturing, recycling, etc.)
- Encourage life-cycle thinking

Tischner and Charter (2001) provide a summary table of sustainable design concerns:

**Table 3: Typical sustainable design concerns**

<b>Economic Issues</b>	<b>Environmental Issues</b>	<b>Social/Ethical Issues</b>
<ul style="list-style-type: none"> <li>○ Technological feasibility</li> <li>○ Financially feasibility</li> <li>○ Short-and long-term profitability</li> <li>○ Adequate pricing</li> </ul>	<ul style="list-style-type: none"> <li>○ Waste minimization</li> <li>○ Cleaner manufacturing</li> <li>○ Cleaner materials</li> <li>○ Eco-efficiency</li> <li>○ Less materials</li> <li>○ Less Energy</li> <li>○ Renewable resources</li> <li>○ Renewable energy</li> <li>○ Recycling</li> </ul>	<ul style="list-style-type: none"> <li>○ Fair trade</li> <li>○ Equitable policies</li> <li>○ 'Good' Employment</li> <li>○ Conditions of work</li> <li>○ Investments in communities</li> <li>○ Support for regional economy</li> <li>○ Cruelty-free</li> <li>○ Satisfaction of real needs</li> <li>○ More customer value</li> <li>○ Better systems</li> <li>○ Participation</li> <li>○ Equality (gender)</li> </ul>

One key element of sustainable business is a life-cycle perspective. A life-cycle analysis (LCA) is used to assess the environmental impact created by a product system from "cradle to grave" (Keoleian & Menerey, 1993). For a product to achieve low life-

cycle environmental costs, designers need to minimize the use of nonrenewable materials mined from the earth's crust, avoid the use of toxic materials, and use living (renewable) resources in accordance with their rate of replenishment (Robert, 1995). Also, the product-in-use must have a low environmental impact and be easily composted, reused, remanufactured, or recycled at the end of its useful life (Kleiner, 1991).

James argues a life-cycle perspective implies an acceptance of some degree of responsibility for the environmental impacts of suppliers of inputs and the consumers of outputs (2001). He adds, "Often the impacts of these upstream and downstream stages of the chain outweigh the impacts of the organization itself, particularly for service industries. In some sensitive industries, failure to identify and improve the environmental and social performance of suppliers can also compromise the saleability of the company's product or service" (2001, p.82).

Lastly, Industrial ecology is another component of environmental/sustainable development. Industrial ecology systematically examines local, regional, and global materials, and energy flows in products, processes, industrial sectors, and economies. It focuses on the potential role of industry in reducing environmental burdens throughout the product life cycle from the extraction of raw materials, to the production of goods, to the use of those goods, and to the management of the resulting wastes.

#### **4.2.3 Does it improve a firm's financial performance?**

There has been much research in the past two decades that links green development to increased financial value. A well-supported argument is that making environmental improvements is often the best way to increase a company's efficiency and, therefore, profitability (Gore, 1992). Others have argued that being green can enhance a firm's image and thus lead to increased sales. These arguments are often referred to as "win-win" solutions because they imply both environmental and financial improvement.

However, there are researchers who are skeptical of these "win-win" situations. Walley and Whitehead argue that green initiatives are tricky and complicated, and they can carry heavy financial burdens (1994). Although they do not deny the existence of win-win situations, Wally and Whitehead believe that they are very rare and will likely be overshadowed by the total cost of a company's environmental program (1994). They argue that companies who pursue ambitious green initiatives without understanding the

importance of trade-offs will probably incur enormous environmental expenditures that will never generate a positive financial return (1994).

There is evidence that supports Wally and Whitehead's argument. At the early stages of green initiatives, there appears to be great deal of "low hanging fruit"; easy and inexpensive behavioral and material changes that result in large emission reductions relative to costs (Hart & Ahuja, 1994; Rooney, 1993). However, after these easy solutions are taken care of, further reductions in waste and emissions become progressively more difficult, often requiring significant changes in processes or even entirely new production technology (Frosch & Gallopoulos, 1989).

Even though they think companies should be skeptical when pursuing green initiatives, Wally and Whitehead do not believe companies should continue to ignore or fight environmental regulatory efforts. They explain, "being conscious of shareholder value while protecting the environment requires, among other things, a deep understanding of the environmental and strategic consequences of business decisions, collaboration with environmental groups and regulators, involvement in shaping legislation (and even avoiding the need for it), and a sincere commitment to cleaning up and preventing pollution" (1994, p.47). They argue the main challenge is knowing how to "pick the shots" that will have the greatest impact (1994). They add, "To achieve truly sustainable environmental solutions, managers must concentrate on finding smarter and finer trade-offs between business and environmental concerns, acknowledging that, in almost all cases, it is impossible to get something for nothing" (1994, p.47).

#### **4.2.4 Formal systems (ISO, EMS, POEM)**

There needs to be a clear set of objectives, strategies and programs for a company if environmental and sustainable development is going to be successful. To enable companies to improve the management of environmental issues, several companies are starting to link green initiatives to formal systems such as ISO 14001 and ERM/EMS, and POEM.



#### **4.2.4.1 ERM/EMS**

Environmentally responsible manufacturing (ERM) is defined as a corporate system that integrates product and design issues with issues of production planning and control and supply chain management in such a manner as to identify, quantify, assess, and manage the flow of environmental waste with the goal of reducing and ultimately minimizing its impact on the environment, while also trying to maximize resource efficiency (Melnik, 2001). Associated with this definition are several important assumptions and premises (Melnik, 2001):

- Underlying this definition is the assumption of a positive relationship between environmental performance and corporate performance.
- ERM decisions are always present and are integrated into the overall business process.
- The ultimate goal of ERM is waste elimination.
- To be ultimately successful, ERM must be viewed as a set of strategically driven decisions that are evaluated by comparing the relative costs and benefits.
- Effective ERM systems must be viewed as a corporate responsibility, not as a legal, manufacturing, engineering, or purchasing responsibility.
- Effective ERM systems must focus on the three Ps - product, process, and packaging.
- ERM is ultimately a cross-functional undertaking. Although ERM is a broad corporate concept, in most firms the actual practice of ERM is executed using systems that come together to form the EMS.

The Environmental Management System (EMS) is the formal corporate management system responsible for the management, organization, measurement, and improvement of environmental performance in the enterprise. The EMS responsibilities include:

- Create an environmental policy.
- Set appropriate objectives and targets.
- Help design and implement a program aimed at achieving those objectives.
- Monitor and measure the program's effectiveness.

- Monitor and measure the effectiveness of the firm's environmental management activities.
- Ensure that the activities of the firm are, at a minimum, compliant with relevant environmental regulations (at the local, state, federal, or international level).
- Help influence critical activities, such as product/ process design and production scheduling, so that environmental concerns and issues are appropriately considered.
- Create corporate understanding of the need for environmental awareness and of the potential advantages offered by becoming more environmentally responsible.
- Identify and introduce appropriate tools intended to improve environmental performance or reduce pollution and educate employees in their use.
- Help identify and correct potential environmental-related problems.
- Review corporate activities with an eye toward improving environmental performance.

As commonly accepted and experienced in environmental management, the optimal results of an EMS require the attuning of the business strategy with the environmental policy so that the environmental dimension is made part of the company's core values, and so that resources or operationalization are provided (Brezet, 2001).

#### **4.2.4.2 Product-oriented Environmental Management**

There is the recognition that the environmental performance of a product should receive increasing importance in assessing the environmental performance of the organization that manufactures that product (Brezet, 2001). Product-oriented Environmental Management (POEM) is defined as a systematic approach to organizing a firm in such a way that improving the environmental performance of its products across their life cycles becomes an integrated part of operations and strategy (Bakker et al. 2002). POEM's have a special focus on the continuous improvement of product eco-efficiency throughout the life-cycle of a product through the systematic integration of eco-design in the company's strategies and practices (Brezet 2001).

The core elements of POEM are (Brezet 2001, p.251):

- The consideration of the eco-efficiency of the company's products at a strategic level through definition of an environmental product policy.
- An evaluation, on a regular basis, of the environmental performance of products (throughout the life-cycle).
- The consideration of environmental criteria in product development processes.
- The formulation of goals to ensure that, in addition to compliance with environmental regulations, the company continuously improves the eco-efficiency of its products, in co-operation with other companies in the product chain.

In addition, creating sufficient flexibility, a broad involvement across functions, and a managerial ability to identify and build the required capabilities are considered to be important factors in the development of POEM (Bakker et al. 2002).

#### **4.2.4.3 ISO14001**

Interest in environmental performance was heightened in the late 1990's by the formal acceptance of the ISO 14000 environmental certification process. With federal environmental regulatory devices such as ISO 14000 (Now Modified to ISO 14001), there has been a growing awareness for firms to be more environmentally responsible. Increasingly, firms are asked by customers, governments, investors, and other stakeholders (e.g., workers and local communities) to reduce pollution and improve overall corporate environmental performance.

The ISO14001 is a standard that specifies requirements for establishing an environmental policy, determining environmental aspects and impacts of products/activities/services, planning environmental objectives and measurable targets, implementation and operation of programs to meet objectives and targets, checking and corrective action, and management review. It also provides the opportunity for companies to be independently assessed as to whether they have met the standard. ISO14001 does not focus on outcomes, such as pollution output, but focuses instead on processes.

#### **4.2.4.4 Criticisms of formal systems**

In spite of the potential opportunities to promote eco-efficiency, it is recognized that formal systems like EMS's and ISO14001 do not guarantee optimal environmental outcomes. The extent of their contribution to environmental optimization and innovation depends on companies' strategic choices. The fact that they do not establish requirements for environmental performance beyond legal compliance, and continuous improvement, cleaner production, and life-cycle thinking are not objectively required, are strong criticisms to the effectiveness of these systems (Brezet, 2001).

In addition, both ISO 9000 and ISO 14000 are essentially corporate, not functional, undertakings and require the investment of significant levels of time, effort, and resources. They are undertakings in which the costs are incurred up front, whereas the benefits of environmental initiatives are often not well defined and are delayed (Melnik 2001).

## **4.3 Barriers to Environmental/Sustainable Improvements**

### **4.3.1 Difficulties with sustainable development**

Surveys and other evidence suggest only a minority of companies are doing much to move towards a sustainable business. The reasons include (James 2001, p. 96):

- Weak financial incentives, with environmental taxes and resource costs being at relatively low levels.
- Weak commitment by managers.
- The complexity of many sustainability issues, which can be beyond the capacity of many organizations to even understand let alone respond to.
- The development of virtual business, which makes it more difficult to understand, identify responsibility for, and manage overall product chains.
- Limited pressure from consumers in terms of actual buying behavior.
- The need to continually respond to changing market conditions makes it difficult for any company to maintain constant improvements over time.

In addition, Tischner and Charter list the following reasons for general lack of awareness or interest in sustainability (2001, p.126):

- Sustainability issues are seen as too long-term and abstract and/or the preserve of academia and government, with the thinking inaccessible to most people.
- Economic and environmental issues are seen as being difficult enough without confusing the issue with complex, 'value-laden' social and ethical issues.
- Wider social and ethical issues are seen as being irrelevant to the debate.

James argues that sustainable business requires a supportive framework that reflects real environmental and social costs (2001). This way, companies will not need to pay quite so much formal attention to sustainability issues but will simply incorporate the prices into their financial calculations (James, 2001). Smart regulation that gives financial incentives and disincentives is also required to steer companies to the long-term changes required (James, 2001).

James believes one of the trickiest problems facing large companies is how to transfer their high level policies into divisions, subsidiaries, and joint ventures (2001). He

explains, “Implementation and co-ordination is usually difficult enough within a single country but it is even more difficult when national cultural differences and sensitivities have to be taken into account. In addition, these problems are compounded with joint ventures because decisions have to be agreed with another partner, who may well have management control” (2001, p. 82). The tendency to greater outsourcing and collaborative partnerships can also make it difficult to identify which organization is responsible for long-term issues such as sustainability (James, 2001).

#### **4.3.2 Barriers to eco-design**

Charter lists a range of internal barriers to eco-design (2001, p.223):

- Limited resources for starting new business.
- Poor communications.
- Organizational structures, cultures, and inertia tending to favor “business as usual.”
- Individual inertia.
- Lack of expertise, awareness and understanding of environmental issues by employees.
- Perceived costs of change.
- Lack of time.
- Existing accounting systems being inadequate to reflect environmental value.
- Design teams having a fear of compromising product quality or production efficiency.

To overcome these barriers, Charter argues that the following strategies will need to be established (2001, p. 224):

- Establishing cross-functional teams to help ensure that there is early consideration of environmental aspects in product development.
- Establishing clear objective targets and performance criteria to help ensure environmental considerations are placed in the right context.
- Training and awareness-raising to help in:

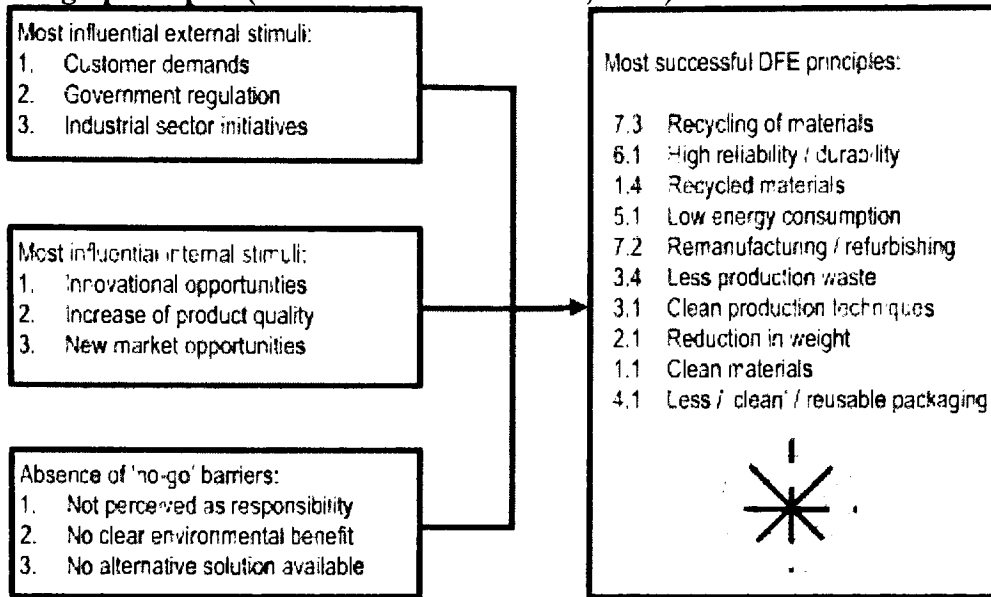
- Communicating and selling the business of eco-design.
- The application and integration of eco-design into management decision making, information and tools to help with the practical application of eco-design.

C. Van Hemel and J. Cramer (2002) examined issues preventing eco-design in small-to-medium-sized companies (SMEs). The authors pointed out SMEs can have distinct advantages over large firms in “greening” their business. They are normally less bureaucratic, able to respond quickly to change and have efficient internal communication networks (2002).

In order to learn which factors stimulate SMEs towards greening their products and which factors hamper them, Van Hemel and Cramer performed an empirical study on the eco-design behavior of 77 Dutch SMEs in 1997. From a list of 33 possible solutions for improving the environmental performance of products, the study showed that the three most successful solutions (implying their realization within 3 years) were: recycling of materials, high reliability/durability, and low energy consumption (2002).

In addition, Van Hemel and Cramer determined that internal stimuli are a stronger driving force for eco-design than external stimuli (2002). The study showed that the most influential internal stimuli were the opportunities for innovation, the expected increase of product quality, and the potential market opportunities. On the other hand, the most influential external stimuli for eco-design are: customer demands, governmental legislation, and industrial sector initiatives. The study also showed that three stimuli acted as “no-go” barriers: ‘no clear environmental benefit’, ‘not perceived as responsibility’ and ‘no alternative solution is available’ (2002). The following table summarizes the results of their study:

**Table 4: The most influential stimuli and barriers, and the 10 most successful eco-design principles (Van Hemel and Cramer, 2002).**



Van Hemel and Cramer concluded that most managers profess a high level of environmental concern, but they have little knowledge of developments in the field of environmental management and they have not introduced formal practices to manage the environmental performance of their businesses (2002). They add, “Any solution to overcome these barriers needs to be inexpensive, co-operative, locally based, flexible, unique and accessible. An eco-design improvement option only stands a chance, if it is supported by stimuli other than the expected environmental benefit alone” (2002, p 452).

#### **4.3.3 Management issues**

Management is most likely to play a huge part in the success or failure of green projects. Melnyk (2001) emphasizes the importance of management support and involvement at all levels in green manufacturing projects. Melnyk argues that two aspects of environmentally responsible manufacturing (ERM) hinder the actual degree of management support. One aspect is the fact that the relationship between ERM-related investments and improved corporate performance has yet to be conclusively established (2001). Another aspect is that there are distinctive disincentives for management to become involved in ERM (2001). Melnyk points out, “because failure to satisfy



governmental regulations can result in not only fines but also imprisonment, and because often the government seeks to assign blame at the highest level of knowledge, there is a strong incentive for management to be largely ignorant of environmental problems and opportunities" (2001, p. 60).

Complicating the situation for environmental managers is the growing array of choices they have for how and when they will respond to environmental pressures (Wally and Whitehead, 1994). Managers today have so many choices that they aren't always sure what to do (Wally and Whitehead, 1994). In addition, making environmental improvements often require careful thought and analysis outside an individual's area of expertise. In fact, many managers frequently juggle a number of issues without a means for setting priorities or a method for integrating those issues into business decision-making (Wally and Whitehead, 1994).

Melnyk also points out that various managers at different levels will respond differently to green initiatives such as ERM or EMS. A study done by Melnyk showed that middle-level management (i.e. supervisors, coordinators, and team leaders) had the most positive view of both ERM and EMS, and also perceived a positive effect on performance (2001). Melnyk believes the reason for this is that these types of managers are in contact on almost a day-to-day basis with the problems of waste and pollution (2001). They also understand what the EMS does and how it affects operations. Thus, these managers have the opportunity to be environmental champions during project implementation, or ISO 14000 certification (2001). Melnyk says this management level "has the opportunity to be the pivotal player in successfully supporting environmental projects, shaping corporate culture, and bringing other levels of management up to speed on environmental process management" (2001, p.65).

In contrast, the study showed that higher-up and low-level managers, because they are not in contact with pollution problems as frequently, tend to see ERM and EMS as more of a constraint and less of an opportunity (2001). The lack of upper-level support for either ERM or EMS would seem to imply greater difficulty in securing funding and approval for an ERM-related investment or initiative such as ISO 14000. Another explanation Melnyk gives for the finding is that top management really does have a low view of ERM/EMS and that any positive views they present on these developments are

for publicity and external consumption, rather than a true statement of what they believe (2001).

In addition, Melnyk's study showed that management perceptions of ERM/EMS are greatly influenced by whether the firm itself is committed to ISO 14000. Generally, managers in firms not committed to ISO 14000, who represent the majority of respondents, did not perceive ERM and EMS in a very positive light (2001). Melnyk believes this finding identifies a major obstacle for the widespread acceptance and use of ERM-related systems, initiatives, and tools (2001).

#### 4.3.4 Cultural issues

Becoming an environmentally friendly, sustainable business is a process of change. It involves abandoning the comfort of the known for the fear and uncertainty of the unknown (James, 2001). James explains, "The cynicism of middle and junior managers after decades of change initiatives is one of the principal impediments to any kind of movement. This is a particularly serious problem when natural environment changes require a great deal of time and effort to understand and implement" (2001 p. 93).

A major problem, due to the complexity of environmental and sustainable issues, is that there is often a widespread feeling that individuals cannot make a difference (James, 2001). Stone (2000) argues that a key component of cleaner production involves changing corporate culture and the attitudes of people. She believes insight can be gained from studying the theories and practices of organizational change, industrial psychology, and sociology. Stone lists possible cultural barriers as (2000):

- **Organizational:** non-involvement of employees, vested decision-making powers, emphasis on production, high staff turnover, lack of recognition.
- **Systemic:** poor record keeping and reporting, inadequate and ineffective management systems, lack of systems for professional development, ad hoc production planning.
- **Attitudinal:** lack of good housekeeping culture, resistance to change, lack of leadership, lack of effective supervision, job insecurity, fear of failure.

Stone also believes management systems contribute significantly to the uptake of cleaner production. System elements include: policy, planning and organization, auditing/assessment, identification, evaluation and implementation of options for improvement, and review (2000).

A research study performed by Stone showed that many non-management employees in an organization have declining or limited knowledge or belief in environmental activities that occur in a company (2000). Stone found that key systemic criteria for environmental management and cleaner production initiatives are the existence of an environmental policy, an on-going process for improving environmental performance, a formal waste reduction program, a waste audit, the identification of cleaner production options, encouragement of staff to identify improvements, and efforts to encourage community input (2000). In addition, Stone considers CEO commitment to be of great importance for the success of cleaner production initiatives.

Ultimately, ambitious environmental goals and programs are useless without enthusiasm among all the workforce (James, 2001). Fortunately, the workforce is beginning to change its attitude. A good number of employees, especially who are young and well educated, already accept the basic rationale for change and may be pressing for it (James, 2001). Many companies have been pleasantly surprised by the high levels of enthusiasm and commitment displayed by their employees towards sustainable and environmental improvements (James, 2001).

## **4.4 Linking Environmental Design to Business Strategy**

### **4.4.1 Creating business value with environmental design**

The fundamental purpose of any private business is to create value for its customers so that its financial stakeholders can be rewarded. James argues, “This is equally true of a sustainable business, which has to meet established criteria of business ‘fitness’ if it is to survive in the long term” (2001, p. 78). He adds, “sustainability will be taken seriously in most companies only if the business case can be demonstrated; which usually means demonstrating that there can be financial cost and benefits” (2001, p. 83). Charter adds, “A firm must define what sustainability means for its business – environmentally, economically, socially, and ethically – as its approach to product issues will be dependent on its vision, commitment and product or service type (2001, p. 242).

These statements underlie the importance of viewing environmental and sustainable development as an integral part of one’s business strategy. A clear set of objectives, strategies, and programs need to be in place for environmental and sustainable development to be successful (Charter, 2001.) A company must determine how environmental and sustainable changes impact their overall business strategy so they can make changes in a manner that not only minimize environmental impact, but also allows them to grow and prosper. A company’s sustainability performance is determined by the extent to which environmental and social issues are an important consideration in its internal business processes (James, 2001).

Cramer and Schot (1993) state that an innovative business strategy should aim at improving the company’s capability to produce environmentally sound products. A strategy such as this should seek to (1993):

- Incorporate environmental considerations into the business strategy of the whole firm, including departments responsible for innovation (such as R&D and marketing divisions).
- Create organizational conditions for synergy between the environmental functions and other functions involved in formulating the business strategy.
- Promote co-operation among firms; the way firms interact on environmental aspects of products. This involves:
  - Exchange of information between firms.
  - The setting of demands on suppliers by user firms,

James adds that an eco efficiency business strategy mind set involves (2001):

- An emphasis on performance that meets “genuine” needs.
- Deriving competitive advantage from consideration of the entire product life-cycle.
- A recognition that eco-efficiency is more of an ongoing process than a once-and-for-all objective.
- Integrating sustainability into the overall business strategy so that it forms a core competence.
- External collaboration to gain information, to influence debates, and to identify business opportunities.

There is evidence to suggest that treating environmental activity as a strategic business issue is very critical to the performance of a firm. Judge and Douglas (1998) empirically tested the assumption that firms with a better-developed capability of integrating environmental issues into the strategic planning process yield superior financial and social outcomes. They determined that positive relationships exist between the level of integration of environmental issues into the strategic planning process and the firm's financial performance, and environmental performance (1998). In addition, they also determined that firms that are able to integrate environmental issues into their various functional areas, will more likely integrate environmental issues into the strategic planning process due to the superior cross functional communication that exists (1998).

The issue of cross-functionality is an important part of environmental strategies. Researchers have found that proper functional coverage is necessary for business success (Hitt et al., 1982; Lorange, 1980; Snow and Hrebiniak, 1980). The logic is that 'functional silos' obstruct effective strategic decision-making and action (Judge 1998). In contrast, when a firm is functionally integrated, it is more collaborative in information sharing and more cohesive in its organizational behavior (Judge 1998).

#### **4.4.2 Integrating eco-design into the organization**

A key issue of sustainability is the extent to which companies integrate environmental considerations into product development alongside cost, quality and

performance (Charter, 2001). The speed of integration will depend on the development of appropriate organizational structures and systems (Charter, 2001). It is essential that the company has a clear view of what it is trying to achieve. This means raising awareness within the organization and the development of a common vision (Charter, 2001). A critical factor is the education, management, and co-ordination of internal and external stakeholders in the product development process (Charter, 2001).

Charter explains the seven stages a company can go through when implementing eco-design (2001, p.224):

1. **Eco-design ignorance:** The company is unaware of eco-design issues.
2. **Eco-design starter:** The environmental manager is in the process of selling the business benefits of eco-design within the company.
3. **Green research and development (R&D) projects:** A pilot green project is being developed in R&D.
4. **Technical integration:** Environmental criteria are being built into engineering procedures.
5. **Semi-eco-design integration:** The company has integrated environmental consideration from idea generation throughout the complete product development process in one business unit or throughout the product family.
6. **Total eco-design integration:** The company has integrated environmental consideration from idea generation throughout the complete product development process across all products and/or services.
7. **Green strategism:** The business has integrated environmental opportunity searches into corporate and business strategies (pre-product development).

Charter explains that as eco-design develops in the firm, it becomes an increasingly strategic and competitive issue. Eco-design issues should be embedded into mainstream organizational management processes. Development of a management framework, clear communication systems, practical eco-design tools and guidelines for managers and employees is essential for successful eco-design integration (Charter 2001). Charter believes it is important that good internal information and communication systems be developed so eco-design can grow and be nurtured. The information system should be focused on separate strategic, tactical, and operational needs. A broad set of tools needs to be developed to cover each stage of the product development process. A key part of this is enabling the flow of eco-design information to the right people, at the right time, and in the right format. Many environmental managers tend to be under-resourced and have to deal with a diverse set of questions from external and internal stakeholders.

Therefore, companies that can manage this information issue will have much better success with eco-design integration (Charter 2001, p. 225-226).

In many firms, environmental managers have weak relationships with those involved in the product development process, and designers and other business functions are unlikely to have received any form of environmental education (Tukker and Haag, 2000). For eco-design to be successful, Charter believes specific job titles and responsibilities need to exist that indicate to the rest of the organization (and outside) that eco-design is recognized as a business issue within the firm (2001). Charter explains that the following job functions are required for eco-design success (2001):

- Eco-design managers: to steer and manage the process.
- Eco-designers (or engineers): to deal with the internal design aspects of the product.
- Eco-designers (industrial or product designers): to deal with the exterior design aspects of the product.
- Hybrid eco-designers: consultants with experience of management and design aspects.

These roles will help form an environmental program with specific policies objectives, and strategies. Charter believes the eco-design manager/s should ideally have experience of the product development process (2001).

Consideration of environmental aspects in product development should be included in the firm's environmental policy. Product development is about the creation of new products and the adaptation or redesign of existing products for new existing markets, and environmental consideration should simply become one important aspect of business analysis. The identification of environmental business and market opportunities may come from the use of strategic environmental tools such as environmental trends analysis (ETA) and green SWOT (strengths, weaknesses, opportunities, and threats) analysis (Charter, 2001).

Once a concrete eco-product idea emerges, the concept should be evaluated against a series of criteria including environmental criteria, marketability, technical feasibility, financial considerations, performance, and quality. The importance of the

criteria will depend on the organization and its own priorities. However, now environmental aspects should become one of the key criteria that new products are assessed against in the product development process (Charter, 2001).

One problem is that typical product designers seldom understand how to employ existing business improvement techniques in a systematic manner for environmental design. To address this, tools and methods are being developed to help identify the business value of environmental product attributes. Fistner *et. al.* (2001) describes how to systematically alter an organization's traditional design process for green design, as well as describes tools that create incentives for eco-design by linking it to business value.

The importance of multifunctional design is becoming increasingly recognized. Multifunctional design teams can facilitate the transfer of environmental knowledge across organizational functions and along the product life-cycle, connecting, for example, designers with manufacturers, recycling centers, and remanufactures early in the design process (Finster *et al.*, 2001). This can greatly speed the product design phase, and increase the effectiveness of eco-design.

The table on the following page presents an outline of eco-design activities in relation to the six stages of the product development process (Brezet and Rocha 2001, p.252):



**Table 5: Suggested eco-design activities in relation to the six stages of the product development process**

Stage	Eco-design activities
<b>1. Orientation phase</b>	<ul style="list-style-type: none"> <li>➤ Form eco-design objectives.</li> <li>➤ Form 'green' marketing objectives.</li> </ul>
<b>2. Definition stage</b> <ul style="list-style-type: none"> <li>➤ Translation of market and other requirements into a concept program of requirements for the new Product.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Involve and gain support of eco-design staff.</li> <li>➤ Carry out environmental benchmarking.</li> <li>➤ Collect information on suppliers.</li> <li>➤ Collect information on other stakeholders. (government, EU, recyclers, users, environmental organizations).</li> <li>➤ Generate 'green' options (assess environmental innovation potential).</li> <li>➤ Validate 'green' options.</li> <li>➤ Draw up an eco-design R&amp;D agenda.</li> <li>➤ Form a concept environmental program of requirements (input to concept program of requirements).</li> </ul>
<b>3. Concept stage</b> <ul style="list-style-type: none"> <li>➤ Define the program of requirements.</li> <li>➤ Specify the concepts of product and process Engineering.</li> <li>➤ Carry out concept styling.</li> <li>➤ Define the suppliers.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Gain eco-design support for environmental specifications and product concepts.</li> <li>➤ Consult environmental material databases and other sources of eco-design expertise (i.e. carry out an inventory).</li> <li>➤ Gauge the 'green' perception (i.e. the emotional response).</li> <li>➤ Draw up an eco-design R&amp;D agenda (technical specifications).</li> <li>➤ Formulate an environmental program of requirements.</li> </ul>
<b>4. Engineering stage</b> <ul style="list-style-type: none"> <li>➤ Detail product and process engineering Requirements.</li> <li>➤ Prepare and start market introduction.</li> <li>➤ Prepare after sales introduction.</li> <li>➤ Suppliers: start serial production.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Consult environmental material databases (i.e. optimize procedures).</li> <li>➤ Seek environmental validation (in terms of production, use, end-of-life, regulations),</li> <li>➤ Form a tactical green marketing and communication plan,</li> </ul>
<b>5. Volume validation</b> <ul style="list-style-type: none"> <li>➤ Test by dealers and customers a small number of series produced trucks,</li> <li>➤ Minor adjustments.</li> <li>➤ After-sales introduction.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Draw up an eco-design after-sales plan (compose user or dealer instructions, etc.).</li> </ul>
<b>6. Evaluation Stage</b> <ul style="list-style-type: none"> <li>➤ Evaluate the project.</li> <li>➤ Evaluate the market response.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Evaluate the product-oriented environmental management system (in terms of procedures, expertise, support).</li> <li>➤ Obtain feedback on eco-design goal setting.</li> </ul>

## **4.5 Resource-Based Vs. Natural-Resource-Based View**

One area of research that may shed light on the relationship between focus and environmental improvement is the resource-based view and the natural resource-based view. They are both theories of competitive advantage based upon the firm's relationship to internal and external sources, which may help us understand the inter-connectedness of a business's resources to its overall business strategy.

### **4.5.1 Resource-based view**

The resource-based view is a theory that takes the perspective that valuable, costly-to-copy firm resources and capabilities provide the key sources of sustainable competitive advantage (Hart, 1995). Resources are defined as all physical and financial assets of a firm, as well as employees' skills and organizational (social) processes (Bakker et al., 2002). A firm's capabilities are the abilities to coordinate, deploy and validate resources to perform value-added tasks (e.g., design for manufacturing, just-in-time production) (Bakker et al., 2002).

Gaining competitive advantage has been extensively studied in management literature. Well-researched sources of competitive advantage include cost leadership, differentiation, timing (e.g., acting early versus late) and commitment level (e.g., entering on a large scale versus more incrementally) (Ghemawat, 1986; Lieberman & Montgomery, 1988; Porter 1980, 1985). Responding to change and preparing for long-term future investments, rather than focusing on only short-term profits, is also critical to sustaining competitive advantage (Hart, 1995).

The connection between firms' capabilities and competitive advantage also has been well established in literature. Ulrich and Lake (1991) stressed the strategic importance of identifying, managing, and leveraging "core competencies" rather than focusing only on products and markets in business planning. Prahalad & Hamel (1990) argued that companies that are better able to understand, nurture, and leverage core competencies will outperform those that are preoccupied with more conventional approaches to strategic business planning.

The resource-based view argues that competitive advantage can be sustained only if the capabilities creating the advantage are supported by resources that are not easily duplicated by competitors (Hart, 1995). The resource-based view identifies key resource characteristics that contribute to a firm's sustained competitive advantage. First, such resources must be valuable and non-substitutable (Barney, 1991; Dierickx & Cool, 1989). That is, they must contribute to a firm capability that has competitive significance and is not easily accomplished through alternative means. Next, strategically important resources must be rare and/or specific to a given firm (Barney, 1991). They must not be widely distributed within an industry and/or must be closely identified with a given organization, making them difficult to transfer or trade (e.g., a brand image or an exclusive supply arrangement) (Hart, 1995). Last, such resources must be difficult to replicate because they are either 'tacit' or 'socially complex' (Teece, 1987; Winter, 1987). Tacit resources are skill-based and people intensive resources that are gained through experience and refined by practice (Hart, 1995). Socially complex resources depend upon large numbers of people or teams engaged in a coordinated action that supersedes the knowledge and abilities of an individual (Hart, 1995).

#### **4.5.2 The Natural-Resource-Based View**

Hart believes that one of the most important drivers of new resource and capability development for firms will be the constraints and challenges posed by the natural (biophysical) environment (1995). Hart argued that natural resources will be increasingly constrained in the future, and firms that better handle this constraint will command a competitive advantage (1995). Hart believed the resource-based-view failed to recognize these constraints imposed by the biophysical (natural) environment. To include environmental considerations into the resource-based view, Hart proposed a "natural-resource-based view of the firm" (1995). He developed a conceptual framework composed of three interconnected strategies: pollution prevention, product stewardship, and sustainable development.

#### **4.5.2.1 Pollution prevention**

Hart explains that an effective pollution-prevention strategy must to seek reduce emissions using continuous-improvement methods focused on well-defined environmental objectives, rather than relying on expensive "end-of-pipe" capital investments to control emissions. Hart mentions that such a strategy is people intensive, and it depends upon tacit skill development through employee involvement (1995). Therefore, the decentralized and tacit nature of this capability makes it difficult to observe in practice and hard to duplicate quickly.

Hart compares the similarity of a pollution prevention strategy to total quality management (TQM), based on its reliance on continuous improvement methods and extensive employee involvement. Because of this, Hart proposes that firms with well-developed quality-management processes, like TQM, will be able to accumulate the resources necessary for pollution prevention more quickly than firms without such skills (1995).

#### **4.5.2.2 Product stewardship**

Product stewardship entails integrating the "voice of environment," into product design and development processes. Through product stewardship, firms can (a) exit environmentally hazardous businesses, (b) redesign existing product systems to reduce liability, and (c) develop new products with lower life-cycle costs (Hart,1995). Hart notes that for start-up firms, product stewardship can form the cornerstone for firm strategy, because there are no pre-existing commitments to products, facilities, or manufacturing processes (1995).

Hart explains that competitive advantage from a product stewardship strategy can be achieved through two primary means: (a) by gaining preferred or exclusive access to important, but limited resources (e.g., raw materials, locations, productive capacity, or customers) or (b) by establishing rules, regulations, or standards that are uniquely tailored to the firm's capability (1995).

Certain requirements exist for a firm to achieve product stewardship. At the most basic level, tools such as DFE and LCA need to be integrated into the firm's product-development process. Beyond this, product stewardship requires firms to take an

environmentally proactive stance toward raw material and component suppliers, which is aimed at minimizing the environmental impact of the entire supplier system (Smart, 1992). In addition, close-working relationships among environmental staff, marketing staff, and customers are also important if the environmental impact of a product is to be minimized.

According to Hart, cross-functional management skills play an important part in a product stewardship strategy (1995). Product stewardship implies an organizational ability not only to coordinate functional groups within the firm, but also to integrate the perspectives of key external stakeholders - environmentalists, community leaders, the media, regulators - into decisions on product design and development (Welford, 1993). Hart states, "Product stewardship should thus afford a firm the opportunity for sustained competitive advantage through accumulation of socially complex resources, involving fluid communication across functions, departments, and organizational boundaries" (1995, p. 1001). Hart believes that firms with demonstrated capability in cross-functional management will be able to accumulate the resources necessary for product stewardship more quickly than firms without such prior capability (1995).

#### **4.5.2.3 Sustainable development**

A sustainable-development strategy is nurtured by a strong sense of social-environmental purpose, which provides the backdrop for the firm's corporate and competitive strategies (Hart, 1995). Sustainable development goes beyond merely solving immediate, internal environmental problems inside a firm. Rather, sustainability implies working over an extended period to develop and deploy low-impact technologies, especially in the emerging markets of less-developed countries (Schmidheiny, 1992).

Hart uses the Hydrogen-powered car as example of such a low-impact technology. Hart points out that such a technology could have important environmental benefits, particularly in the developing world where the energy and transportation infrastructures are still being defined (1995). Hart adds, "sustainable development should thus afford opportunity for sustained competitive advantage through accumulation of rare and firm-specific resources, involving a shared vision of the future and focus on new technology and competency development" (1995, p.1003)

Pursuing a sustainable development strategy involves both substantial investment and a long-term commitment to market development. A long-term, shared vision is required to leverage an environmentally conscious strategy into the developing world that includes low-impact technology and products as the basis for market entry and development (Schmidheiny, 1992). Creating such a shared vision of the future requires strong moral leadership (Bennis & Nanus, 1985), an empowering social process, and reaching deep into the management ranks (Campbell & Yeung, 1991; Hart, 1992). Hart believes firms that have a demonstrated capability in establishing shared vision will be able to accumulate the resources necessary for sustainable development more quickly than firms without such prior capability (1995).

#### **4.5.3 Interconnectedness**

Hart also explains how the three strategies associated with the natural-resource-based view of the firm are interconnected. He uses two terms to explain this: “path dependence” and “embeddedness” (1995).

##### **4.5.3.1 Path dependence**

Hart points out that there is a certain sequential logic to the three environmental strategies. Without first making significant progress in pollution-prevention front, Hart believes it will be difficult to successfully adopt a product-stewardship strategy (1995). He adds, “If a firm attempts to differentiate products as “green” or environmentally responsible while continuing to produce high levels of production waste and emissions, it would seem risky because stakeholders (e.g., regulators, environmental groups) could easily expose this anomaly, destroying the firm's credibility and reputation” (1995, p. 1005).

Furthermore, Hart believes a firm's successful pursuit of a sustainable-development strategy may be dependent upon having first demonstrated competence in product stewardship. Hart mentions that early accumulation of resources in pollution prevention and product stewardship may actually provide the foundation upon which a sustainable-development strategy can be gradually added (1995).

#### **4.5.3.2 Embeddedness**

Hart also goes on to explain that there are also advantages of pursuing the three strategies in parallel. For example, it can be argued that one of the most effective ways to prevent pollution is to alter the product design (product stewardship) rather than to seek only "process" changes (Allenby, 1991). Similarly, if pollution prevention can eliminate process steps, thereby cutting cycle times, it can clearly lead to faster response in the marketplace, facilitating a product-stewardship strategy (1995). Furthermore, the cross-functional coordination and stakeholder integration associated with product stewardship might also help identify opportunities for reducing emissions, just as empowered employees and "green teams" might suggest improvements in products (Makower, 1993). Hart adds, "if a firm takes a purely sequential path, it may fail to take advantage of the clear synergies that exist across the strategies" (1995, p. 1007). "Just as the product-development process is enhanced when design and manufacturing are planned concurrently, environmental performance also should be improved through the simultaneous (or at least overlapped) accumulation of pollution-prevention and product-stewardship capabilities" (1995, p. 1007).

In addition, Hart argues that a sustainable-development strategy facilitates and accelerates capability development in pollution prevention and product stewardship and vice versa. He explains "a shared vision of 'sustainability' in a firm might help focus and even accelerate the pace of resource accumulation and capability building in pollution prevention and product stewardship, in addition to guiding shifts in technology and market focus called for by sustainable development" (1995, p. 1007).

## 4.6 Summary of Literature Review

The belief that the success of a company is heavily dependent on how it is strategically structured, organized, and managed forms the basic principal of focused factories. To summarize, focus involves structuring an organization's resources to support and enhance the specific competitive factors of their products and/or services. The key is establishing consistency throughout the organization so that various functional elements of the firm match the firm's overall business strategy and product requirements. This consistency makes the firm's main goals and priorities clearly identifiable and understandable which, in turn, simplifies the firm and makes it much more manageable.

From the literature, it appears that successful environmental and sustainable initiatives also depend heavily on the way the firm is structured and organized. The literature emphasizes the following issues that affect the success of environmental/sustainable improvements:

- The need to examine the entire life-cycle of the product.
- The need to determine and understand tradeoffs associated with environmental changes.
- The need for formal environmental systems, programs, and procedures.
- The need for environmental/sustainable goals to be a core part of the business strategy.
- Creating business value through environmental/sustainable efforts.
- The need for the whole organization to be directed towards the same environmental goals.
- The importance of proper management involvement/support.
- The importance of employee involvement/awareness.
- The level of bureaucracy in the organization.
- The level of cross-functionality (coordination) within the organization.

In addition, several works (Charter, 2001; Walley and Whitehead, 1994; Rothenberg *et. al.*, 1992; Hart, 1995) emphasize the importance of integrating environmental issues into the core business strategy of a company. It is my belief that



thoroughly understanding a company's business and manufacturing strategies, and how environmental issues impact these strategies, is the key to making successful and long lasting environmental improvements. I believe focusing helps form a solid manufacturing and business platform on which to promote the "smart" integration of environmental issues into a company. In the following section, I will develop specific hypothesis on why I believe focused factories are better suited for making successful environmental improvements than non-focused factories.

## **5. Theoretical Development**

### **5.1 Developing the Hypotheses**

The literature reviewed in the previous section reflects the strategic and organizational implications of environmental/sustainable changes. For “green” initiatives to be successful, a firm must integrate environmental issues into the core business strategy so that environmental changes not only improve the firm’s environmental performance but its competitive performance as well. In addition, the speed and success of environmental integration will depend the development of appropriate organizational structures and systems (Charter, 2001). A culture needs to be created that can properly identify key problems, and effectively create and implement appropriate solutions.

These kinds of issues suggest a link between the level of focus of an organization and its ability to implement environmental and sustainable improvements. Just as a company needs to focus its manufacturing/marketing/business strategies to sustain a competitive advantage, a company needs to “focus” its environmental and sustainable strategies so they complement the competitive factors of its business and not clash with them. In addition, a focused factory will create an infrastructure that will be much more adept at managing and handling environmental and sustainable issues.

The work done here proposes that focused factories are better suited for making environmental and sustainable improvements. The following sections develop specific propositions that apply to the three major components of focus: competitive strategy development, process reorganization, and infrastructure reorganization.

#### **5.1.2 Competitive strategy development**

Works by Hart (1995), Judge (1998), Walley and Whitehead (1994), and Charter (2001) all discuss the importance of using environmental or sustainable improvements to gain a competitive advantage. A major barrier to environmental efforts is that firms often invest large amounts of time and resources into environmental development without analyzing the tradeoffs between business and environmental concerns (Walley and Whitehead 1994). Firms that follow this approach usually end up with investments that very rarely generate a positive financial return (Walley and Whitehead, 1994). Firms

need to create business value with their environmental efforts by knowing how to pick and choose the environmental solutions that will have the most positive impacts.

This can be applied to the concept of focused factories because focus is essentially a theory of gaining a competitive advantage. Focus implies competitively arranging and aligning a firm's resources in manner that allows them to skillfully accomplish a particular set of manufacturing tasks demanded by the company's overall strategy and marketing objectives (Skinner, 1974). In a focused environment, every decision is based on how it impacts the business/marketing/manufacturing strategy. Therefore, environmental and sustainable concerns would likely be analyzed in the same manner. Focused companies would determine how environmental and sustainable changes affect their business strategy, so changes can be made that enhance, rather than compromise, the firm's competitive position. This leads to the first formal proposal as to why focused factories are better suited over traditional factories for the development and implementation of environmental and sustainable improvements:

**Proposition 1: The focused factory will be more likely than the traditional factory to strategically use environmental/sustainable improvements to create business value or to gain a competitive advantage.**

Focus emphasizes the importance of establishing and understanding a specific, consistent business strategy. A firm would lose focus if environmental efforts clashed and conflicted with the goals outlined in its corporate strategy. Therefore, in a focused factory, competitive environmental/sustainable issues will likely be integrated into the overall business strategy, which will lead to the development of clear, specific environmental strategies. This is important because many researchers believe that establishing clear, specific environmental strategies derived from the company's corporate strategy is essential for successful environmental and sustainable development (Charter, 2001; Walley and Whitehead, 1994; Rothenberg *et. al.*, 1992; Hart, 1995). Hence, the next proposal:

**Proposition 2: The environmental strategies will be embedded in the overall corporate strategy of a focused factory.**

The resource-based view argues that achieving and sustaining a competitive advantage depends on how a firm uses its resources. This holds true for the natural-based-resource-view, which includes environmental and sustainable considerations as additional sources of competitive advantage. The ideals from these views are essentially embedded in the theory of the focused factory. Firms that are focused will outperform conventional factories because they will be better able to understand, nurture, and leverage core competencies. They know what their factory does and doesn't do. Focus implies a deeper knowledge and understanding of the processes, products, and infrastructure of a firm, and how they affect the competitive priorities for that firm. Therefore, the focused factory should be better able to understand how its resources can be deployed to make positive environmental and sustainable improvements. This is important because environmental and sustainable issues are inherently complex and companies are often not clearly aware of their full environmental impact. Truly sustainable and environmental improvements require efforts from all facets of the organization, and at all stages of the product's life cycle. Being more focused should make it easier to examine a product's life cycle and thus make appropriate environmental improvements. A focused plant should simply nurture appropriate environmental strategies, such as DfE, LCA, EMS, etc. Hence, the next proposal:

**Proposition 3: The focused factory will implement more effective environmental strategies than the traditional factory.**

Focus also implies a deeper understanding of the company's marketing opportunities. Plants can become non-competitive if their policies are not focused on the key manufacturing tasks essential to compete successfully in their various markets. Focus requires a company to identify the key customer demands for its products (cost, quality, deliverability, etc.), and then to arrange the firm's resources in a manner that complements these demands. Therefore, in a focused factory, it is essential that the firm understands how the market drives its business and operational decisions.

From a green marketing perspective, the customer plays an important role in environmental and sustainable development. If the company's market sectors demand

environmental improvement, a company will be more likely to respond to making these improvements. Because focus factories are more properly aligned to marketing strategies, they will be better able to identify the specific environmental needs demanded by their particular market segments.

In addition, environmental issues can also be seen as a competitive priority. Berry *et al.* argued that “qualifiers to which a customer would be particularly sensitive, such as cleanliness or chemical purity standards, are designated as order-losing sensitive” (1991, p.365). A firm can receive negative publicity, a bad reputation, and/or loss of market share if the firm continues to pollute. This means that poor environmental aspects of a product or service can cause some firms to lose business (order losers). On the other hand, due to regulatory standards or benchmarking performance measures, firms in many industries have to sustain a certain level of environmental performance simply to maintain their competitive positions (order qualifiers). In addition, outstanding, industry-leading environmental performance for a product can actually win business orders (order winners). Seen in this manner, a focused factory would treat environmental aspects of a product as either order losers, qualifiers, or winners. Attaching such a competitive implication to environmental issues would significantly raise environmental awareness, and the firm would respond accordingly. For some focused companies, if the environmental aspects for certain products were powerful enough winners or qualifiers, they could actually focus their products and processes around distinguishing environmental attributes. Hence, the next proposal:

**Proposition 4: The focused factory will have a better understanding than the traditional factory of the environmental concerns expressed in their market segments.**

### **5.1.3 Process/product reorganization**

A defining argument for focus is that it is often not apparent to either marketing or operations managers that it is difficult for a single operating unit to develop superior competitive capabilities in serving markets that require very different operations strategies (Berry et al, 1991). This argument can be applied to environmental strategies as well, because there seems to be no single best model for solving environmental problems.

Environmental problems can have multiple causes, and hence multiple solutions.

Rothenberg *et al.* (1992) argued that each firm needs to develop its own environmental strategy that best fits the specific external and internal conditions it faces; the firm must match external pressures and opportunities with its unique internal characteristics.

Den Hond (1996) determined that environmental strategies differ among firms in the same industry that face the same issue because these firms assess differently a set of potential solutions. Den Hond believes environmental solutions and strategies are developed based on these three factors (1996, p. 65):

- The extent to which problem solving is complementary to the firms' core activities.
- The firm's perception of the existence of technological options in problem solving that improves its capabilities.
- Its perception of the existence of opportunities for appropriating profits associated with problem solving activities.

The above arguments re-emphasize the importance of strategically analyzing environmental issues. As mentioned earlier, environmental issues have strategic implications if their impact is high enough to put core elements of the company's business at risk or to change the company's cost structure, and if they allow managers considerable discretion in how to respond (Walley and Whitehead, 1994).

Knowing this, it is important to know how environmental strategies affect a firm's competitive priorities. Emphasis on different competitive priorities likely require different environmental strategies. For example, costly recycling programs may have an effect on the ability to satisfy a competitive "low-cost" requirement. Material reduction or substitution may impact the quality of a product. Eco-design changes to a product may require significantly different production processes, which may impact throughput or deliverability speed. Complex reuse or remanufacturing logistics may affect the flexibility of a product. Because environmental changes can affect the structural and functional characteristics of a product, it is essential for highly competitive firms that environmental changes do not compromise its key competitive factors.

Therefore, a focused factory would provide the foundation for proper environmental strategies to be developed. In a focused factory, each focused unit has a

specific, consistent competitive priority that the entire unit revolves around. Environmental and sustainable strategies will be specifically custom-tailored to the individual focused unit needs. The focused factory will strive to create environmental solutions that support, not compromise, the main competitive priority. Environmental and sustainable improvements will be more appropriate and complementary, thus creating more business value. Hence, the next proposal:

**Proposition 5: The focused factory will be more likely than the traditional factory to develop proper, specific environmental strategies for each focused unit, and their corresponding competitive priorities.**

It is argued that environmental impacts can occur in any of the stages of a product's life cycle, including extraction and processing of raw materials, production of intermediate and final products, consumption, and disposal, as well as the transportation of products between any of these stages. A major insight of life-cycle management is that choices in one stage of a product's life-cycle can result in environmental impacts at other stages. Choices in product design may not only cause pollution by its own production process, but they may also cause environmental degradation downstream when the product is sold and the firm is no longer in control.

The interface between the firm's production process and the natural environment is quite complex. It requires detailed and specialized knowledge of production processes and product design, as well as insight into up and downstream material transformation processes (Den Hond, 1996). Reducing environmental impact via pollution prevention schemes demands a thorough diagnosis of the total production process, including the overall material flows and transformation processes, as well as energy efficiency in specific steps of the production process (Den Hond, 1996).

Focus is a helpful method to deal with these issues. Because focused units are separated with clearly defined goals and priorities, they are much more manageable. The product's processes are clearly connected and laid out, making it much easier to identify the resources associated with each phase of the life-cycle. Therefore it is much easier to identify the environmental impacts associated with each phase of the life-cycle.

In addition, the process for a product is separated from conflicting processes for other products that do not share the same competitive priorities. Therefore, the focused unit only has to focus on improving the environmental performance of a limited set of products and processes. They also do not have to worry about hindering the production of any conflicting products, because they would simply be delegated to another focused unit. Hence, the next proposal:

**Proposition 6: In a focused factory, the environmental design changes for a particular product or process will be less likely to contend with other conflicting products or processes than they would in the traditional factory.**

#### **5.1.4 Infrastructure reorganization**

Properly designed infrastructures and organizational systems are key determinants of both focused factories and successful environmental improvements. A major problem for firms is the tendency to add too many layers of management and other specialists as they grow according to economies of scale. This results in a big, expensive, slow-moving bureaucracy that becomes unaware of the distinct differences within its markets, and the specific manufacturing tasks required to support these differences (Hill, 1989). Firms in this position cannot quickly and effectively identify and respond to market requirements and, thus, their competitiveness is diminished.

At the same time, the more bureaucratic an organization is the harder it will be to make environmental and sustainable improvements. Centralized organizational structures, cultures, and inertia tend to favor “business as usual”, and fail to develop the resources necessary to make environmental changes (Charter, 2001). Support and funding for any environmental improvements will have to pass through several layers of management, and companies will need to establish strict company policies and programs in order to get everybody working toward environmental improvement.

A focused factory brings forth a more decentralized, less hierarchical infrastructure. Relevant staff is assigned to the focused unit, not merely nominated to a central unit. Responsibility for the management and direction of the staff involved clearly belongs to the focused unit. This leads to the development of a more appropriate infrastructure, where unnecessary procedures and support staff are eliminated. The focused unit has more freedom to make necessary changes to its apparatus which, in turn,



will make it easier to implement environmental and sustainable solutions. Hence, the next proposal:

**Proposition 7: The less bureaucratic infrastructure associated with focus will promote smoother implementation of environmental/sustainable improvements than in the traditional factory.**

Cross-functionality is another important infrastructural element for successful environmental and sustainable development. Making environmental improvements often require careful thought and analysis outside an individual manager's area of expertise. Multifunctional design teams can help facilitate the transfer of environmental knowledge across organizational functions and along the product life cycle (Finster, 2001). This can greatly speed the product design phase, and increase the effectiveness of eco-design. In addition, establishing cross-functional teams helps to ensure that environmental aspects are considered early in product development (Charter 2001).

In the traditional infrastructure, operating departments function independently and often make decisions based on their own objectives, rather than the company as a whole. In a focused factory, the behavior of individual departments become complementary actions aimed at the firm's objectives rather than conflicting actions aimed at departmental objectives. Focus requires cross-functional communications and involvement of all employees to ensure consistent and appropriate decision-making. This cross-functionality will, therefore, help accelerate a multi-functional issue such as environmental development. Hence, the next proposal:

**Proposition 8: The cross-functional activity associated with focus will make it easier to determine, implement, and nurture environmental issues than in the traditional factory.**

For true environmental and sustainable improvements to be fully realized, there must be strong dedication, support and involvement from all levels throughout the organization. However, even if this enthusiasm and support is generated, an organizational system and infrastructure must be developed that promotes, achieves, and sustains actual environmental goals and objectives.

Research suggests that the following organizational issues are barriers to environmental development: non-involvement of employees, vested decision-making powers, high staff turnover, lack of recognition, poor record keeping & reporting, inadequate & ineffective management systems, lack of systems for professional development, ad hoc production planning, resistance to change, lack of leadership, lack of effective supervision, and manager cynicism (Charter, 2001; James, 2001; Stone, 2000).

In many firms, environmental managers have weak relationships with those involved in the product development process, and designers and other business functions are unlikely to have received any form of environmental education (Tukker and Haag, 2000). For eco-design to be successful, Charter believes specific job titles and responsibilities need to exist that “indicate to the rest of the organization (and outside) that eco-design is recognized as a business issue within the firm” (2001 p.227).

In a focused firm, the culture is much more unified. Everybody knows what the competitive priorities are and what they have to do to make their plant succeed. Specific infrastructure is designed (job responsibilities, duties, systems, procedures) to ensure the competitive priorities are satisfied.

Just as specific competitive goals and priorities are embedded in the culture of a focused firm, the benefits of environmental/sustainable development will similarly be embedded in the culture as well. An environmentally conscious focused firm will integrate competitive environmental issues into its corporate strategy, and then create an infrastructure that promotes these environmental issues. Just as a focused firm creates an appropriate infrastructure to meet a specific competitive need, an environmentally conscious focused firm will create an appropriate infrastructure to meet a specific environmental or sustainable need. Specific environmental positions, job duties, and responsibilities will be assigned and delegated to ensure specific environmental and sustainable goals are achieved. Hence, the next proposal:

**Proposition 9: Focused factories will be more likely than the traditional factory to create and assign appropriate environmental positions, job duties, and responsibilities.**

True focus brings forth revised supervisory and management roles (Shue, 1996). The jobs and processes in a focused factory are simplified dramatically, and the focused plant will tend to need fewer supervisors. The simplicity helps eliminate most of the potential for making quality mistakes. Therefore, managers don't have to spend as much time on traditional supervision, and can shift their efforts toward process and product improvement. Thus, managers in a focused firm will have more time to develop and manage environmental improvements. Hence, the next proposal:

**Proposition 10: Managers in a focused factory will be more geared towards process and product improvement, and thus have more time and resources to develop environmental improvements than in the traditional factory.**

Finally, employee involvement is also important for focus success. Because workers are responsible for much of the coordination that occurs in the plant, they can facilitate focus by maintaining consistency of actions in the plant. They can also bring to management's attention inconsistent demands being placed on them by different products processes, and customers. Involving direct labor can help maintain and improve focus.

Similarly, involving direct labor is also very useful for identifying and correcting environmental problems. These workers are located directly at the source of environmental problems and are in contact with the products and processes on a daily basis, so naturally they will be ideal sources for helping to identify and solve environmental controls.

If a focused factory better utilizes and empowers its employees to create a certain competitive advantage, then it will likely better utilize and involve its employees in environmental and sustainable development. This leads to the final proposition:

**Proposition 11: The employees in a focused factory will be more likely to be aware, educated, and involved in environmental/sustainable improvement than in the traditional factory.**

All eleven propositions are summarized below:

1. The focused factory will be more likely than the traditional factory to strategically use environmental/sustainable improvements to create business value or to gain a competitive advantage.
2. The environmental strategies will be embedded in the overall corporate strategy of a focused factory.
3. The focused factory will implement more effective environmental strategies than the traditional factory.
4. The focused factory will have a better understanding than the traditional factory of the environmental concerns expressed in their market segments
5. The focused factory will be more likely than the traditional factory to develop proper, specific environmental strategies for each focused unit, and their corresponding competitive priorities
6. In a focused factory, the environmental design changes for a particular product or process will be less likely to contend with other conflicting products or processes than they would in the traditional factory.
7. The less bureaucratic infrastructure associated with focus will promote smoother implementation of environmental/sustainable improvements than in the traditional factory.
8. The cross-functional activity associated with focus will make it easier to determine, implement, and nurture environmental issues than in the traditional factory.
9. Focused factories will be more likely than the traditional factory to create and assign appropriate environmental positions, job duties, and responsibilities.
10. Managers in a focused factory will be more geared towards process and product improvement, and thus have more time and resources to develop environmental improvements than in the traditional factory.
11. The employees in a focused factory will be more likely to be aware, educated, and involved in environmental/sustainable improvement than in the traditional factory.

## 5.2 Selecting the Final Hypotheses

From the theoretical development, eleven propositions were proposed. However, for the scope of this project, designing a survey to test every one of these eleven hypotheses would be too ambitious. Adequately testing all of these eleven hypotheses would simply require too many questions for a reasonable survey. Also, some of the hypotheses would probably be better examined through a case study or some other experimental design method rather than a survey. In addition, many of the hypotheses were similar enough to be able to combine some and narrow them down to a testable amount. After some careful thought and consideration, the following hypotheses were selected from the original eleven propositions for testing:

**Hypothesis 1: The focused factory will be more likely than the traditional factory to strategically use environmental/sustainable improvements to create business value or to gain a competitive advantage (Proposition 1).**

**Hypothesis 2: The focused factory will implement more effective environmental strategies than the traditional factory (Proposition 3).**

**Hypothesis 3: The focused factory will be more likely than the traditional factory to create and assign appropriate environmental positions, job duties, and responsibilities (Proposition 9).**

These three hypotheses were chosen because they seemed to best capture the basic components of focus and how it influences environmental responsibility. Most of the other propositions were seeking to get at ideas that were generally a component of one of these central ideas. These propositions were also ideal candidates because they seemed reasonable enough, in scope, to test through a survey. That is, they did not require significantly detailed information that could only be properly captured through a case study, or some other controlled experiment.

## **6. Research Methodology**

### **6.1 Why a survey?**

The primary approach for gathering the data in this study was a survey. The survey was designed to collect data pertaining to the respondents' "degree of focus", as well as measures pertaining to environmental performance. A survey was chosen as the preferred method for testing because, through a survey, data can be obtained from a wide variety of plants with different manufacturing styles and organizational structures. Gathering information from only a few specific sources (i.e., case study) is less desirable because it would give us only firm-specific information that could not be generalized to manufacturing as a whole.

### **6.2 Strengths and Weaknesses of a Survey (Barribeau *et al*, 2005)**

#### **Strengths:**

- Surveys are relatively inexpensive.
- Surveys are useful in describing the characteristics of a large population. No other method of observation can provide this general capability.
- They can be administered from remote locations using mail, email or telephone.
- Consequently, very large samples are feasible, making the results statistically significant even when analyzing multiple variables.
- Many questions can be asked about a given topic giving considerable flexibility to the analysis.
- There is flexibility at the creation phase in deciding how the questions will be administered: as face-to-face interviews, by telephone, as group administered written or oral survey, or by electronic means.
- Standardized questions make measurement more precise by enforcing uniform definitions upon the participants.
- Standardization ensures that similar data can be collected from groups then interpreted comparatively (between-group study).
- Usually, high reliability is easy to obtain: by presenting all subjects with a standardized stimulus, observer subjectivity is greatly eliminated.

#### **Weaknesses:**

- A methodology relying on standardization forces the researcher to develop questions general enough to be minimally appropriate for all respondents, possibly missing what is most appropriate to many respondents.
- Surveys are inflexible in that they require the initial study design (the tool and administration of the tool) to remain unchanged throughout the data collection.
- The researcher must ensure that a large number of the selected sample will reply.

- It may be hard for participants to recall information or to tell the truth about a controversial question.
- As opposed to direct observation, survey research (excluding some interview approaches) can seldom deal with "context."

## 6.3 Survey Design

The survey consists of four main sections. The first section gathers information on the respondent's plant "degree of focus". The next three sections gather information corresponding to the three selected hypotheses.

### 6.3.1 Focus questions

From the literature review, measuring a true and accurate "degree of focus" is acknowledged by many researchers as a very difficult thing to do. Due to the diverse and complex nature of businesses, it is very hard to determine a standard measure of focus. However, companies that are focused should have certain organizational traits that are more apparent than companies who are not focused. Therefore, the survey questions pertaining to focus were designed to examine "traits of focus", rather than to seek a true measure of a plant's "degree of focus".

The traits of focus examined in the survey are as follows:

- Consistent manufacturing flow.
- Less-bureaucratic infrastructure.
- Clearly prioritized competitive requirements.
- Focusing on doing just a few things well, rather than trying to address a large number of customer demands.
- Having a consistent business strategy.
- Utilizing multi-functional teams and input in the decision making process
- Cross-functionality.
- Empowered direct labor force.
- Employee awareness of company business goals and objectives.
- Placement of products with similar manufacturing characteristics and/or volumes into separate cells or areas.
- A business strategy that clearly establishes a limited set of priorities for manufacturing.
- Less required amount of traditional production supervision.
- Rarely having to expedite product.

The focus questions were generalized in a manner so that they could relate to any manufacturing plant or company, regardless if the respondent had any idea of what “focus” was or not.

### **6.3.2 Hypothesis 1 survey questions**

***Hypothesis 1: The focus factory will be more likely than the traditional factory to use environmental and sustainable improvements in a strategic manner to create business value or to gain a competitive advantage.***

To test this hypothesis, the survey questions were designed to capture information on the respondents’ level of environmental performance, as well as the extent to which environmental improvements have created business value for the respondents. It should be noted that proactive environmental improvement was specifically assessed; the level of respondent’s compliance with federal and industry environmental standards and regulations is not relevant to our study as all companies must be in compliance, regardless of their level of focus.

The measures examined for this are as follows:

- The level of cost savings due to environmental efforts.
- The level of reduction of waste, emissions, and materials due to environmental improvements.
- The improvement of image due to environmental efforts.
- The level of increased earning potential due to environmental efforts.
- The extent to which the plant goes beyond compliance issues to proactively seek further environmental improvement.
- The extent to which the plant’s business strategy includes environmental goals and priorities.
- The extent to which environmental improvements are made to improve the profitability of the plant.
- If environmental responsibility is emphasized through a well-defined set of environmental policies and procedures.

Ideally, the more focused plants will experience more positive financial and environmental improvement due to environmental efforts than the less focused plants. In addition, the more focused plants should have well-defined environmental goals and priorities embedded in their business strategy.



### 6.3.3 Hypothesis 2 survey questions

***Hypothesis 2: The focused factory will implement more effective environmental strategies than the traditional factory.***

To test this hypothesis, the survey questions were designed to determine what types of environmental strategies the respondents were implementing. Specifically, the questions looked for these environmental strategies, which based upon the literature review can be viewed as environmental “best practices”:

- Life cycle analyses (LCA).
- Eco-design or Design for the Environment (DfE) practices.
- The use of recycled parts and/or materials in the production process.
- The establishment of an environmental management system (EMS).
- Replacement of hazardous materials in products or processes with more environmentally benign products.
- Environmental benchmarking practices.

Ideally, there should be more evidence of the above strategies and practices found in the more focused plants than in the less focused plants.

### 6.3.4 Hypothesis 3 survey questions

***Hypothesis 3: The focus factory will be more likely than the traditional factory to create and assign appropriate environmental positions, job duties, and responsibilities.***

The survey questions for this hypothesis examine the appropriateness of the respondents' infrastructure regarding environmental responsibility. Theoretically, environmental responsibility should be more integrated in the more focused plants. Specifically, the questions for this hypothesis examined these environmental issues relating to infrastructure:

- If approval and funding for environmental improvements is easy to acquire.
- If there are dedicated environmental positions assigned in the plant.
- If many employees are involved in environmental improvement.
- If managers are too busy with day-to-day responsibilities to spend time on long-term environmental projects.
- If direct labor plays a role in environmental improvement.
- If environmental responsibility is valued highly in the company culture.
- If environmental goals are clearly communicated to all plant personnel.

- If an adequate amount of training in environmental awareness is provided to hourly/direct labor employees within the plant.
- If an adequate amount of training in environmental awareness is provided to managers and supervisors within the plant.

## **6.4 Question format for the survey**

The survey was designed to only contain closed-ended questions. Closed-ended question have many advantages over open-ended questions. These include: closed-ended questions are more easily analyzed, and they allow for statistical interpretation; closed-ended questions can be more specific, thus more likely to communicate similar meanings; and closed-ended questions take less time from the interviewer, which typically generates a higher response rate (Fowler, 1995).

All of the questions were arranged in an Agree-Disagree format, which is commonly used in surveys. The basic process was to form the question into a general statement, such as “Our business strategy includes environmental goals and priorities.” The survey respondents were then to decide how much they agreed or disagreed with that statement pertaining to their plant. All of the survey constructs were operationalized using five-point Likert scales, where 1 = Completely Disagree, 2 = Somewhat Disagree, 3 = Undecided / Neutral, 4 = Somewhat Agree, and 5 = Completely Agree.

## **6.5 Sample Selection/Unit of Analysis**

The sample selection for the survey was manufacturing plants in the Western New York area. The sample was not industry specific, as long as it was essentially a manufacturing plant. Selecting a specific industry for the study was considered, but eventually was opted against because it would most likely generate too similar data for both environmental performance and the level of focus. A specific plant size was not absolutely defined, but the survey was designed to target plants with 25-1500 employees.

The unit of analysis for the study is defined as a manufacturing plant. The plant manager was targeted as the main respondent to represent this unit of analysis. Plant managers were the ideal choice, as they are most likely the best suited to assess the plant on both a strategic and environmental level.

## 6.6 Survey Reliability and Validity

### 6.6.1 Reliability

Reliability is the extent to which an experiment, test, or any measuring procedure yields the same result on repeated trials. If a research tool does not yield consistent measurements, researchers will be unable to satisfactorily draw conclusions, formulate theories, or make claims about the generalizability of their research.

One step toward ensuring consistent measurement in a survey is to ensure that each respondent in the sample is asked the same set of questions (Fowler, 1993). The researcher would like to be able to make the assumption that differences in answers stem from differences among respondents rather than from differences in stimuli to which respondents were exposed (Fowler, 1993). Careful wording, format, content, etc. can reduce significantly the subject's own unreliability.

Fowler argues that a reliable question has the following properties (1993):

- The question means the same thing to every respondent.
- The kinds of answers that constitute as an appropriate response are communicated consistently to all respondents.

Threats to reliability in a survey include (Fowler 1993):

- Inadequate wording.
- Incomplete/ incorrect wording.
- Questions that can mean different things to different respondents.
- Open-ended questions.

Reliability can be assessed by examining the internal consistency of the items. One common method to do this is Cronbach's Alpha (Nunnally, 1978). Test-re-test reliability is another form of reliability that provides evidence of the consistency of the instrument over time. However, this involves re-administration of the instrument and is, therefore, rarely ever done in large-scale survey research.

Surveys tend to be strong on reliability if carefully constructed. Survey research presents all subjects with a standardized stimulus, and so goes a long way toward eliminating unreliability in the researcher's observations.

### 6.6.2 Validity

Validity refers to the degree to which a study accurately reflects or assesses the specific concept that the researcher is attempting to measure. While reliability deals with the accuracy of the actual measuring instrument or procedure, validity is concerned with the study's success at measuring what the researchers set out to measure. There are basically four types of validity: construct validity, conclusion validity, internal validity, and external validity.

Construct validity is the extent to which the theoretical constructs of treatment, outcome, population, and setting have been successfully operationalized. Operationalizing is the process of translating the theoretical constructs of the hypothesis into specific instances of the research design (Judd and Kenny, 1981). Construct validity basically lies at the heart of the scientific process and addresses the question of what the instrument is actually measuring (Malhotra, 1998).

Conclusion validity is the extent to which the research design is sufficiently precise or powerful to detect effects on the operationalized outcome should they exist. A greater power implies that there is a greater probability of finding statistical relationships among variables.

Internal validity is the extent of the detected effects on the operationalized treatment rather than other competing cases. In experimental designs using survey research, it is possible to control extraneous effects on the dependent variable by using experimental controls or by homogenizing the sample groups (Malhotra, 1998).

External validity is the extent to which the effects observed among operationalized constructs can be generalized to theoretical constructs other than those specified in the original research hypothesis.

Surveys have tendencies to be weaker on validity. The artificiality of the survey format puts a strain on validity. Since people's real feelings are hard to grasp in terms such as "agree/disagree," "support/oppose," "like/dislike," etc., these can only be approximate indicators of the real true value the measurement is seeking.

However, there are methods available improve the validity of a survey. One way is to assess the appropriateness of the items and constructs found in the survey, which is referred to as content validity. This is typically done by assessing the relevance of the

theoretical basis for the items from the literature. It also includes the adoption of existing (and preferably validated) scales, pre-testing, and assessing the clarity as well as problems in the wording (i.e., bias, ambiguity, inappropriateness, double-barreled questions) (Malhotra, 1998).

Internal validity is often difficult to assess in survey research, as most survey designs aren't traditional experimental designs with a designated control group. However, in the absence of experimental designs, researchers should try to justify internal validity through an informal discussion of why causality exists or why alternate explanations are unlikely.

Statistical conclusion error is traditionally assessed through the well-known Type I and Type II error calculations. Type I error (the probability of finding a relationship when none exists) is indicated by the alpha level in statistical tests, while the lack of power leads to a type II error (the probability of incorrectly sustaining the null hypothesis). The single most important factor in establishing adequate power for a test is sample size. Sample sizes of at least 100 are desirable for survey research (Malhotra, 1998).

To improve the validity of a survey, Malhotra states that ideal survey attributes include (1998):

- A clearly identified unit of analysis.
- The instrumentation consistently reflects the unit of analysis,
- The respondents chosen are appropriate for the research question.

Malhotra also notes that another ideal attribute pertains to *triangulation*, or multiple methods to better assess the variables of interest (1998). These methods can include written instrumentation (i.e., a multi item measure), multiple respondents (more than one response per company), additional interviews with organizational representatives, and objective measures (i.e., financial data) (1998). However, although these cross validation techniques clearly enhance confidence in the validity of the results, they can be significantly costly in terms of both time and effort and may not be practical in many instances.

Fowler states that there are basically three steps to the improvement of validity in subjective survey measures (1993, pp 92-93): The first step is to make the questions as reliable as possible through careful question design. The next step is to have proper scales

with an adequate number of points on the scale. For example, it is more desirable to have a 7 or 5-point Likert scale as opposed to a three-point scale or a Yes/No selection. The last step to improve the validity of a subjective measure involves asking multiple questions, with different question forms that measure the same subjective state. Multiple questions help even out response idiosyncrasies and improve the validity of the measurement process (Fowler, 1993).

## 6.7 Improving survey questions

Effective survey questions tend to have these traits (Barribeau *et al*, 2005):

- Questions should be written in a straightforward, direct language that is not caught up in complex rhetoric or syntax, or in a discipline's slang or lingo.
- Questions should be kept short and simple. Respondents should not be expected to learn new, complex information in order to answer questions.
- Specific questions are, for the most part, better than general ones. Research shows that the more general a question is the wider the range of interpretation among respondents.
- Questions should not be overly personal or direct, especially when dealing with sensitive issues.

These types of questions should typically be avoided (Barribeau *et al*, 2005):

- Double-barreled questions that force respondents to make two decisions in one. For example, "Do you think women and children should be given the first available flu shots?" This does not allow the responder to choose whether women or children should be given the first shots.
- Double negative questions.
- Hypothetical questions. These are typically too difficult for respondents since they require more scrutiny. For example, "If there were a cure for cancer, would you still support euthanasia?"
- Ambiguous questions. Respondents might not understand the question.
- Biased questions. For example, "Don't you think that suffering terminal cancer patients should be allowed to be released from their pain?" Researchers should never try to make one response option look more suitable than another.
- Questions with long lists. These questions may tire respondents or respondents may lose track of the question.

Survey design tips (Fowler 1993):

- Start out with easy questions.
- Questionnaire should be self-explanatory.
- Use closed-ended questions.
- Questions forms should be few in number.
- Survey should be clear and uncluttered.
- Provide redundant information where necessary.

## **6.8 Final Comments on the Survey**

Based on the above ideas, a great amount of time and consideration was taken to make the survey as reliable and as valid as possible. Questions were carefully selected to capture the most relevant information possible based on the theoretical research.

Meticulous measures were taken to ensure the questions were clear, concise, and as direct as possible. All the questions were formatted in same agree-disagree format to make the survey as uncomplicated as possible. The complete final survey can be found in appendix A.

## **7. Survey Administration and Collection**

The survey was designed to be administered through the internet. A webpage was created where the user could type in their Name, Position, Company Name, Company Description, and # of Employees. The user would then answer each survey question by selecting the appropriate radio button (Strongly Disagree, Somewhat Disagree, Neutral, Somewhat Agree, Strongly Agree) for each question. After each question was answered, the user clicked a “Submit” button and the data was automatically sent electronically to a specific email database.

Acquiring survey data proved to be an extremely difficult task. With all of the “spam” mail that is flooding businesses today, acquiring survey data is becoming increasingly difficult. Simply just emailing the survey with a basic cover letter to a company yielded no significant results. In addition, contacting the key personnel within the company proved to be extremely difficult. Obtaining a completed survey typically required an extensive amount of phone work; contacting HR personnel, leaving several messages, follow up calls, etc. A lot of unexpected time was spent trying to gather survey data.

The survey was sent out to numerous manufacturing companies in New York State. A handful of surveys were sent to other parts of the Northeast US, including Ohio, Pennsylvania, Connecticut, and Massachusetts. A total of 256 different companies were contacted for the survey. Of the 256 different companies contacted, a total of 60 surveys were returned, generating a response rate of 23%. The majority of respondents were companies located in the Western NY area (Rochester, Buffalo, Syracuse, etc.). This is probably because companies in Western NY were more familiar with R.I.T, and thus more willing to participate in the survey. The majority of the survey takers were plant managers or engineers, and the size of the companies typically ranged between 25 – 1500 employees. The following is a listing of the industries of the companies that participated in the survey, as well as a range of the number of employees:



**Table 6: Industries which participated in the survey**

A/C components	Machine tool manufacturer
Access hardware	Hair products
Aerospace	Manufacturer of Surgical Needles
Aerospace OEM	Medical Products
Automotive	Metal Industry
Automotive Component Supplier	Metrology solutions
Diffraction grating manufacturer	Motorcycle Cable Manufacturing
Digital Copiers	Non-Contact Metrology (Manufacturing)
Electro Mechanical Assembly	Optical Fiber Cable
Electro-magnetic components	Plastic injection molded products
Eye Care - Medical	Plastic Injection Molding
Fluid Control Products and Actuation Systems	Powdered Metal Component Producer
Glass and Ceramic Products	Production Machine Shop
Heavy Duty Diesel Manufacturer	Radar and Sonar Manufacturing
Imaging Products	Refrigeration & AC Component Mfg.
Industrial Products	Semi-conductor manufacturer
Industrial pump manufacturer	Sheet metal manufacturer
Injection Molding	Subcontract Manufacturing
Iron castings	Telecommunications
Job Shop	Tire Mfg.
Machine Tool Manufacturer	Utility monitoring equipment

**Table 7: Range of number of employees per respondents:**

# of employees	# of responses
25-100:	11
101-500:	19
501-1000:	8
1001 1500:	6
1501+ :	7
Unknown:	9

## 8. Statistical Analysis of the Survey Data

### 8.1 Developing the Degree of Focus Score

The first step in analyzing the survey data was to assign a “Degree of Focus” score for each respondent. This gave a basic measure as to how closely a respondent’s company represented an actual “focused factory” based on the answers they selected.

The first 14 questions on the survey pertained to focus. The questions are as follows:

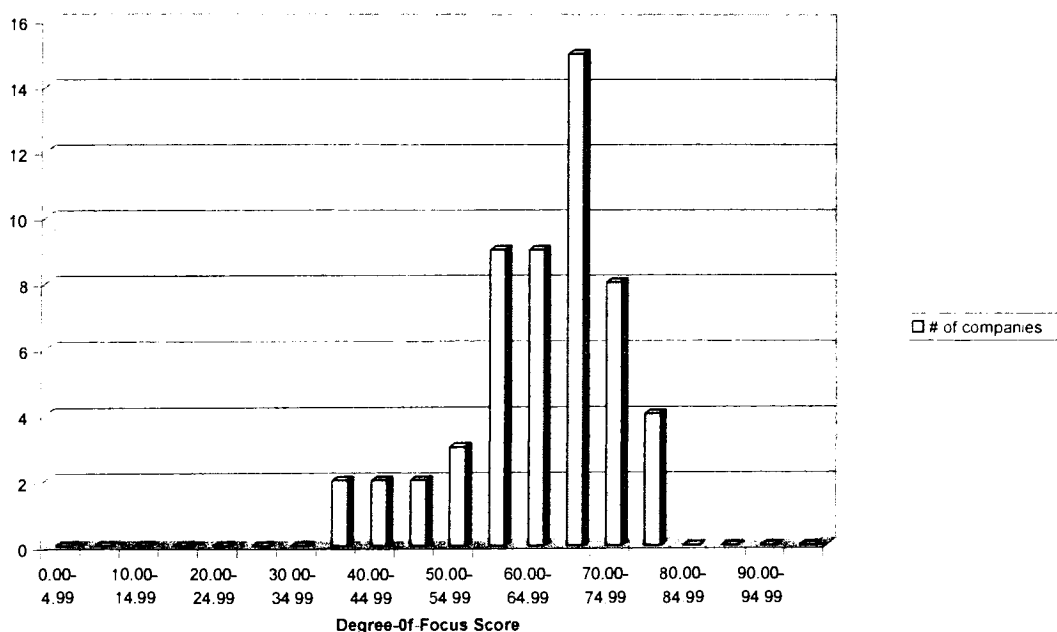
- Question 1:** Varying customer orders and demands disrupt the flow of our manufacturing processes.
- Question 2:** Our company’s level of bureaucracy hinders our ability to implement process and/or product improvements.
- Question 3:** Certain competitive requirements (ex. Low cost, high quality, fast delivery, etc.) are clearly prioritized for each product we make.
- Question 4:** We will accept a new customer order that requires significant modifications to our manufacturing processes.
- Question 5:** Our plant tries to address a large number of customer demands.
- Question 6:** Our business strategy changes often.
- Question 7:** We rely on input from multifunctional teams (i.e. Engineering / Marketing / Purchasing / Operations, etc.) in plant decision making.
- Question 8:** We place products with similar manufacturing characteristics and/or volumes into separate cells or areas.
- Question 9:** Our direct labor force is given more responsibility than in traditional companies.
- Question 10:** Each employee is well aware of our company’s business goals and objectives.
- Question 11:** Our functional departments routinely co-ordinate their activities.
- Question 12:** Our business strategy clearly lays out a limited set of priorities for manufacturing.
- Question 13:** Our plant relies on an extensive amount of traditional production supervision.
- Question 14:** Our plant has to expedite product frequently.

Each question was answered in a 5-point Agree-Disagree format (1=Strongly Disagree, 2=Somewhat Disagree, 3=Neutral, 4=Somewhat Agree, 5=Strongly Agree). This generated a set of answers for each respondent that indicated how closely each company associated their company’s practices and traits, with the ones given in the questions. For example, selecting a 1 or 5 represented the lowest and highest association

with the particular question, where selecting a 3 represented a “medium” or “neutral” association, and so on. For each respondent, the “degree of focus” score (DFS) was obtained by simply summing their selected answers for questions #1-14, dividing that sum by a max sum of 70, and multiplying that number by 100 to obtain a percentage. It should be noted that, due to the way some of the questions were structured, some of the scores needed to be “reversed” to create an accurate DFS (A “1” would actually represent a “5”, a “2” would actually represent a “4”, etc.). An example of this would be question #1: Varying customer orders and demands disrupt the flow of our manufacturing processes. Here a response of “1” (Completely Disagree) would most represent high focus.

The distribution of degree of focus scores for each survey respondent is represented in the following bar graph. From looking at the graph, the data seems to be more or less normally distributed, perhaps slightly skewed to the left.

**Table 8: Distribution of Degree-of-Focus Scores (DFS) for 60 survey respondents**



Once a DFS was calculated for each respondent, the respondents were separated into separate groups: The “Low Focus Group” and the “High Focus Group”. This was simply done by arranging the 60 respondents in ascending order based on their DFS’s,

and placing the 30 respondents with the lowest DFS's in the "Low Focus" group and the other 30 respondents with the highest DFS's in the "High Focus" group. Therefore, it is assumed that the respondents placed in the High Focus group more closely resemble a theoretical focused factory than the respondents placed in the Low Focus group. The set of degree of focus scores obtained can be seen in the following table:

**Table 9: Lowest 30 and highest 30 degree of focus scores from the survey**

Lowest 30 degree of focus Scores (Low Focus Group)			Highest 30 degree of focus Scores (High Focus Group)		
35.71	55.71	60.00	65.71	67.14	70.00
37.14	55.71	61.43	65.71	68.57	71.43
42.86	57.14	61.43	65.71	68.57	71.43
44.29	58.57	61.43	65.71	68.57	72.86
47.14	58.57	61.43	65.71	68.57	74.29
47.14	58.57	61.43	65.71	68.57	75.71
51.43	58.57	62.86	65.71	70.00	77.14
51.43	58.57	62.86	67.14	70.00	77.14
54.29	58.57	62.86	67.14	70.00	78.57
54.29	60.00	64.29	67.14	70.00	87.14

To ensure that these two groups were statistically different, a two sample T-test was performed using Minitab software. The Minitab output is displayed below:

## MINITAB OUTPUT:

### Two-Sample T-Test and CI: Low focused group, High focused group

Two-sample T for Low Focus group vs High Focus group

	N	Mean	StDev	SE Mean
Low Focus group	30	55.52	7.67	1.4
High Focus group	30	70.24	4.92	0.90

Difference =  $\mu$  (low focused group) -  $\mu$  (high focused group)

Estimate for difference: -14.7123

95% CI for difference: (-18.0556, -11.3691)

T-Test of difference = 0 (vs not =): T-Value = -8.64 P-Value = 0.000 DF = 49

The low P-value of 0.000 shows that the two groups are, indeed, statistically different. Now that the sample has been divided into Low Focus and High Focus groups, the responses to the remaining environmental questions in the survey can be examined to see if any correlation does or does not exist between the two groups.

## 8.2 Testing Hypothesis 1

***Hypothesis 1: The focus factory will be more likely than the traditional factory to use environmental and sustainable improvements in a strategic manner to create business value or to gain a competitive advantage***

As mentioned in Section 6, to test this hypothesis, the survey questions were designed to capture information on the respondents' overall level of environmental performance, as well as the extent to which environmental improvements have created business value for the respondents. The questions included in the survey for hypothesis 1 were:

- Question 15:** Our plant has experienced significant cost savings due to environmental efforts.
- Question 16:** Our plant has experienced a significant reduction in waste and/ or emissions due to environmental efforts.
- Question 17:** Our plant has significantly reduced energy usage through environmental improvements.
- Question 18:** Our plant has significantly reduced the consumption of raw materials due to environmental improvements
- Question 19:** Our plant has improved its image due to environmental efforts.
- Question 20:** Our plant has increased its earning potential due to environmental efforts.
- Question 21:** Our plant goes beyond compliance issues to proactively seek further environmental improvement.
- Question 22:** Our business strategy includes environmental goals and priorities.
- Question 23:** Our plant makes environmental improvements to improve the profitability of the plant.
- Question 24:** Environmental responsibility is emphasized through a well defined set of environmental policies and procedures.

### 8.2.1 Testing each survey question 15 - 24

The first step in testing hypothesis 1 was to determine if correlation exists between the High Focus and Low Focus groups' responses for each of the above questions. A major question of interest is: Is the degree of focus for a company

*independent* (not related) to environmental performance as described in questions 15-24, or are they *dependent* (related)? If the High Focus and Low Focus groups' responses are independent, it is essentially saying that knowledge of one variable (degree of focus) gives us no information about the values of another variable (the answers for questions 15-24). When they are dependent, it is essentially implied that knowledge of the degree of focus for a company is helpful in predicting the values of questions 15-24.

For each question, the null and alternate hypothesis is defined as follows:

$H_{0x}$ : The responses to question  $x$  are independent to the degree of focus.

$H_{ax}$ : The responses to question  $x$  are **not** independent to the degree of focus.

To test these hypotheses, chi square analysis was performed for each question 15-24. The chi-square test of independence is used to examine the relationship between the distribution of scores for 2 categorical variables. The chi-square test will tell whether the scores on the two variables are independent or dependent.

Computing the chi-squared statistic involves arranging data into what is known as a contingency table. A contingency table shows the responses of subjects to one variable as a function of another variable. For each survey question, there were 5 possible answer outcomes (1=Strongly Disagree, 2=Somewhat Disagree, 3=Neutral, 4=Somewhat Agree, 5=Strongly Agree). Therefore, for each question, a contingency table was established that tabulated the total number of responses per each answer choice (1-5) for both the High Focus group and the Low Focus group. For example, the contingency table for Question #15 is shown below:

**Table 10: Contingency table for question 15**

Question 15:	Total # of responses per each answer choice				
	1	2	3	4	5
Low Focus Group	4	13	8	3	2
High Focus Group	2	3	15	7	3

Once contingency tables are established, the next step in computing the Chi-squared statistic is calculating what is known as the “expected frequency” for each cell observation. The formula for computing this is as follows:

$$\text{Expected Cell Frequency} = (\text{Row Total} * \text{Column Total}) / N$$

Using this, the expected values for Question 15 are calculated below:

**Table 11: Contingency table for question 15 with calculated expected values**

Question 15:		Total # of responses per each answer choice					row total:
		1	2	3	4	5	
Low Focus Group	observed	4	13	8	3	2	30
	expected	3	8	11.5	5	2.5	
High Focus Group	observed	2	3	15	7	3	30
	expected	3	8	11.5	5	2.5	
column total:		6	16	23	10	5	N = 60

The chi-squared test statistic,  $X^2$ , can then be calculated by using the following formula:

$$X^2 = \sum_{\text{all cells}} (\text{Observed} - \text{Expected})^2 / \text{Expected}$$

The rejection region would be  $X^2 \geq X^2_{\alpha, k-1}$ , where  $k$  is the number of possible outcomes, and  $k-1$  is equal to the degrees of freedom. Using the above formula, the chi-square statistic for Question 15 is calculated as:

$$X^2 = 0.333 + 3.125 + 1.065 + 0.8 + 0.1 + 0.333 + 3.125 + 1.065 + 0.8 + 0.1 = 10.847$$

The result of 10.847 is then compared to the tabular value of  $X^2_{\alpha, k-1}$ . Because there were  $k = 5$  possible outcomes,  $k-1 = 4$ . At the  $\alpha = .05$  level of significance, the tabular value of  $X^2_{.05, 4}$  is 9.49. At the  $\alpha = .10$  level of significance, the tabular value of

$\chi^2_{10,4}$  is 7.78. Therefore, at  $\chi^2 = 10.847$ , the null hypothesis can be rejected at both the .05 and .10 level of significance and conclude that the companies' responses to question 15 are not independent to the degree of focus. In other words, it can be concluded that there is a statistically significant difference in the responses to Question 15 between the High Focus and Low Focus groups at both the 0.05 and 0.1 level.

When computing the chi square statistic, it's important to pay attention to what are known as minimum threshold frequencies. If a contingency table generates very low raw observed frequencies, the expected frequencies may also be too low for the chi-square to be appropriately used. The following minimum frequency thresholds should be obeyed (Devore, 1995):

- For a 1 X 2 or 2 X 2 table, expected frequencies in each cell should be at least 5.
- For a 2 X 3 table, expected frequencies should be at least 2.
- For a 2 X 4 or 3 X 3 or larger table, if all expected frequencies but one are at least 5 and if the one small cell is at least 1, chi-square is still a good approximation.
- In general, the greater the degrees of freedom (i.e., the more values/categories on the independent and dependent variables), the more lenient the minimum expected frequencies threshold.

There were no problems associated with the minimum threshold frequencies for this experiment. The actual expected values for each chi square analyses can be found in the appendices.

The same testing procedure was repeated for the remaining questions for Hypothesis 1. The results are listed in the following table:

**Table 12: Contingency tables for questions 15-24 with calculated Chi-squared values**

		total # of responses					Chi-square stat:	$\chi^2_{(.05,4)}$	Reject Null?	$\chi^2_{(.1,4)}$	Reject Null?	P Value
		1	2	3	4	5						
Question 15:	Low Focus	4	13	8	3	2	10.84	9.49	Y	7.78	Y	0.028
	High Focus	2	3	15	7	3						
Question 16:	Low Focus	2	8	8	9	3	5.074	9.49	N	7.78	N	0.28
	High Focus	2	2	11	9	6						



Question 17:	Low Focus	4	7	11	8	0	6.29	9.49	N	7.78	N	0.178
	High Focus	3	4	12	6	5						
Question 18:	Low Focus	6	10	8	4	2	2.096	9.49	N	7.78	N	0.718
	High Focus	3	8	11	6	2						
Question 19:	Low Focus	4	8	10	5	3	3.714	9.49	N	7.78	N	0.446
	High Focus	2	4	11	10	3						
Question 20:	Low Focus	5	12	8	3	2	10.86	9.49	Y	7.78	Y	0.029
	High Focus	2	3	13	8	4						
Question 21:	Low Focus	4	8	6	11	1	10.844	9.49	Y	7.78	Y	0.028
	High Focus	0	3	10	11	6						
Question 22:	Low Focus	6	7	10	4	3	8.619	9.49	N	7.78	Y	0.071
	High Focus	1	3	11	6	9						
Question 23:	Low Focus	4	11	8	5	2	7.845	9.49	N	7.78	Y	0.097
	High Focus	1	4	12	8	5						
Question 24:	Low Focus	3	8	5	9	5	5.635	9.49	N	7.78	N	0.228
	High Focus	2	2	9	9	8						

Looking at the results of the chi square test, the survey questions in which the null hypothesis is rejected at the  $\alpha=.10$  level of significance are:

- Question 15:** Our plant has experienced significant cost savings due to environmental efforts.
- Question 20:** Our plant has increased its earning potential due to environmental efforts.
- Question 21:** Our plant goes beyond compliance issues to proactively seek further environmental improvement.
- Question 22:** Our business strategy includes environmental goals and priorities.
- Question 23:** Our plant makes environmental improvements to improve the profitability of the plant.

The questions in which the null hypothesis is not rejected at the  $\alpha=.10$  level of significance are:

- Question 16:** Our plant has experienced a significant reduction in waste and/ or emissions due to environmental efforts.
- Question 17:** Our plant has significantly reduced energy usage through environmental improvements.

- Question 18:** Our plant has significantly reduced the consumption of raw materials due to environmental improvements
- Question 19:** Our plant has improved its image due to environmental efforts.
- Question 24:** Environmental responsibility is emphasized through a well defined set of environmental policies and procedures.

### 8.2.2 Creating and testing the “Hypothesis 1 Score”

Similar to how the degree of focus score was created, for each respondent, a “Hypothesis 1 Score” (H1S) was obtained by simply summing their selected answers for questions #15-24, dividing that sum by a max sum of 50, and multiplying that number by 100 to obtain a percentage. Again, based on the way some of the questions were structured, some of the scores needed to be “reversed” to create an accurate H1S. The H1S scores for all 60 respondents are shown in the table below:

**Table 13: Hypothesis 1 Scores**

The "Hypothesis 1 Scores" (H1S) for each of the 60 respondents					
22.00	44.00	56.00	60.00	72.00	82.00
24.00	46.00	56.00	62.00	72.00	84.00
26.00	46.00	56.00	62.00	72.00	86.00
26.00	48.00	56.00	64.00	72.00	86.00
30.00	48.00	58.00	64.00	74.00	86.00
34.00	50.00	60.00	66.00	74.00	88.00
36.00	52.00	60.00	66.00	76.00	90.00
36.00	54.00	60.00	68.00	76.00	94.00
40.00	54.00	60.00	68.00	78.00	96.00
42.00	54.00	60.00	70.00	80.00	100.00

These scores were then arranged in a contingency table that tabulated the total number of scores above and below the median score of 60.00 for both the High Focus and Low Focus groups (the two respondents who scored exactly the median score of 60.00 were omitted). This contingency table is shown below:

**Table 14: H1S contingency table**

Hypothesis 1	Below H1S Median	Above H1S Median
High Focus	7	20
Low Focus	18	9

A chi square test was then performed where:

- Null Hypothesis:  $H_0$ : The H1S scores are independent to the degree of focus.  
 Alternate Hypothesis:  $H_a$ : The H1S scores are **not** independent to the degree of focus.  
 Test statistic:  $X^2 = \sum_{\text{all cells}} (\text{Observed} - \text{Expected})^2 / \text{Expected}$   
 Rejection region:  $X^2 \geq X^2_{\alpha, k-1}$ , where  $k = 2$ .

The results of the test are listed in the following table:

**Table 15: H1S chi-squared values**

Hypothesis 1	Below H1S Median	Above H1S Median	Chi-square stat:	$X^2_{(.05, 1)}$	Reject Null?	$X^2_{(.1, 1)}$	Reject Null?	P Value
High Focus	7	20	9.012	3.843	Y	2.706	Y	0.003
Low Focus	18	9						

At  $X^2 = 9.012$ , the null hypothesis can be rejected at both the .05 and .10 level of significance and conclude that the H1S scores are not independent to the degree of focus. In other words, it can be concluded that there is a statistically significant difference in the H1S scores between the High Focus and Low Focus groups at both the 0.05 and 0.01 level.

### 8.2.3. Conclusions on Hypothesis 1

In summary, 5 of the 10 individual survey question for Hypothesis 1 were found to be not independent from the degree of focus. In addition, it can be concluded that the H1S scores were not independent to the degree of focus as well. Based on this information, there is significant statistical evidence that supports Hypothesis 1. In other words, statistical evidence suggests that the focused factory, may in fact, be more likely to use environmental and sustainable improvements in a strategic manner to create business value or to gain a competitive advantage than the traditional factory. Further analysis for Hypothesis 1 is discussed in section 9.

## 8.3 Testing Hypothesis 2

***Hypothesis 2: The focused factory will implement more effective environmental strategies than the traditional factory (Proposition 3).***

As mentioned in Section 6, to test this hypothesis, the survey questions were designed to capture information on the types of environmental strategies the respondents were implementing. The questions included in the survey for hypothesis 2 were:

**Question 25:** We perform life cycle analyses for our products as a part of our environmental efforts.

**Question 26:** Our plant uses recycled parts and/or materials in our production process.

**Question 27:** Our plant has an environmental management system (EMS) in place or is working to implement an EMS.

**Question 28:** We have successfully replaced hazardous materials in our products and/or processes with more environmentally benign products.

**Question 29:** Environmental practices, procedures, and systems within our plant are compared with best-in-class on a regular basis.

**Question 30:** We bring environmental considerations into the early stages of product development.

### 8.3.1 Testing each question 25-30

In exactly the same fashion for Hypothesis 1, chi-squared analysis was performed to determine if correlation exists between the High Focus and Low Focus groups' responses for each of the above questions for Hypothesis 2. The same hypothesis test was formulated, where:

Null Hypothesis:	$H_{0x}$ :	The responses to question $x$ are independent to the degree of focus.
Alternate Hypothesis:	$H_a$ :	The responses to question $x$ are <b>not</b> independent to the degree of focus.
Test statistic:	$X^2 = \sum_{\text{all cells}}$	$(\text{Observed} - \text{Expected})^2 / \text{Expected}$
Rejection region:	$X^2 \geq X^2_{\alpha, k-1}$ ,	where $k = 5$ .

The results are listed in the following table:

**Table 16: Contingency tables for question 25-30 with calculated Chi-squared values**

		total # of responses										
		1	2	3	4	5	Chi-square stat: $X^2_{(.05, 4)}$	Reject Null?	$X^2_{(.1, 4)}$	Reject Null?	P Value	
Question 25:	Low Focus	7	6	8	7	2	2.415	9.49	N	7.78	N	0.66
	High Focus	3	5	11	9	2						
Question 26:	Low Focus	3	7	3	12	5	1.125	9.49	N	7.78	N	0.89
	High Focus	4	6	4	9	7						
Question 27:	Low Focus	7	4	5	7	7	1.25	9.49	N	7.78	N	0.87
	High Focus	5	4	7	5	9						
Question 28:	Low Focus	1	4	8	11	6	6.187	9.49	N	7.78	N	0.186
	High Focus	1	2	3	10	14						
Question 29:	Low Focus	6	3	4	4	3	4.499	9.49	N	7.78	N	0.343
	High Focus	3	3	12	7	5						
Question 30:	Low Focus	6	4	12	8	0	8.935	9.49	N	7.78	Y	0.063
	High Focus	1	3	14	7	5						

Looking at the results of the chi square test, the survey questions in which the null hypothesis is rejected at the  $\alpha=.10$  level of significance are:

**Question30:** We bring environmental considerations into the early stages of product development.

The questions in which the null hypothesis was not rejected at the  $\alpha=.10$  level of significance are:

**Question 25:** We perform life cycle analyses for our products as a part of our environmental efforts.

**Question 26:** Our plant uses recycled parts and/or materials in our production process.

**Question 27:** Our plant has an environmental management system (EMS) in place or is working to implement an EMS.

**Question 28:** We have successfully replaced hazardous materials in our products and/or processes with more environmentally benign products.

**Question 29:** Environmental practices, procedures, and systems within our plant are compared with best-in-class on a regular basis.

### 8.3.2 Creating and testing the “Hypothesis 2 score”

In the same manner the Hypothesis 1 Scores were derived, a “Hypothesis 2 Score” (H2S) was calculated for each respondent by summing their selected answers for questions 25-30, dividing that sum by a max sum of 30, and multiplying that number by 100 to obtain a percentage (Again, based on the way some of the questions were structured, some of the scores needed to be “reversed” to create an accurate H2S). The scores were then arranged in a contingency table that tabulated the total number of scores above and below the median score of 63.33 for both the High Focus and Low Focus groups (the respondents who scored exactly the median score of 63.33 were omitted). This contingency table is shown below:

**Table 17: H2S contingency table**

Hypothesis 2	Below H2S Median	Above H2S Median
High Focus	10	15
Low Focus	13	12

A chi-squared test was performed where:

Null Hypothesis:  $H_0$ : The H2S scores are independent to the degree of focus.

Alternate Hypothesis:  $H_a$ : The H2S scores are not independent to the degree of focus.

Test statistic:  $X^2 = \sum_{\text{all cells}} (\text{Observed} - \text{Expected})^2 / \text{Expected}$

Rejection region:  $X^2 \geq X^2_{\alpha, k-1}$ , where  $k = 2$ .

The results are shown in the table below:

**Table 18: H2S Chi-squared calculation**

Hypothesis 2	Below H2S Median	Above H2S Median	Chi-square stat:	$X^2_{(.05, 1)}$	Reject Null?	$X^2_{(.1, 1)}$	Reject Null?	P Value
High Focus	10	15	0.725	3.843	N	2.706	N	0.395
Low Focus	13	12						

At  $X^2 = 0.725$ , the null hypothesis cannot be rejected either the .05 and .10 level of significance and is concluded that the H2S scores are independent to the degree of

focus. In other words, it can be concluded that there is no significant difference in the H2S scores between the High Focused and Low Focus groups at either the 0.05 and 0.01 levels.

### **8.3.3. Conclusions on Hypothesis 2**

In summary, only 1 of the 6 individual survey questions for Hypothesis 2 were found to be not independent from the degree of focus. In addition, it could not be concluded that the H2S scores were not independent to the degree of focus. Based on this information, there is no significant statistical evidence to support Hypothesis 2. In other words, there is no evidence to believe to that the focused factory will implement more effective environmental strategies than the traditioanl factory. Further analysis for Hypothesis 2 is discussed in the section 9.

## 8.4 Testing Hypothesis 3

***Hypothesis 3: The focus factory will be more likely than the traditional factory to create and assign appropriate environmental positions, job duties, and responsibilities***

As mentioned in section 6, the survey questions for Hypothesis 3 examined the appropriateness of the respondents' infrastructure regarding environmental responsibility. According to my theory, environmental responsibility should be more integrated in the more focused plants. The questions included in the survey for hypothesis 3 were:

- Question 31:** Approval and funding for environmental improvements is easy to acquire.
- Question 32:** We have dedicated environmental positions assigned in the company.
- Question 33:** Many employees are involved in environmental improvement.
- Question 34:** Our managers are too busy with day-to-day responsibilities to spend time on long-term environmental improvement projects.
- Question 35:** Direct labor plays an important role in environmental improvement.
- Question 36:** Environmental responsibility is valued highly in the company culture.
- Question 37:** Environmental goals are clearly communicated to all plant Personnel.
- Question 38:** An adequate amount of training in environmental awareness is provided to hourly/direct labor employees within our plant.
- Question 39:** An adequate amount of training in environmental awareness is provided to managers and supervisors within our plant.

### 8.4.1 Testing each question 31-39

Again, in exactly the same fashion for Hypothesis 1 and 2, chi-squared analysis was performed to determine if correlation exists between the High Focus and Low Focus groups' responses for each of the above questions for Hypothesis 3. The same hypothesis test was formulated, where:

- |                       |                                 |  |
|-----------------------|---------------------------------|--|
| Null Hypothesis:      | $H_{0x}$ :                      | The responses to question $x$ are independent to the degree of focus.            |
| Alternate Hypothesis: | $H_a$ :                         | The responses to question $x$ are <b>not</b> independent to the degree of focus. |
| Test statistic:       | $X^2 = \sum_{\text{all cells}}$ | $(\text{Observed} - \text{Expected})^2 / \text{Expected}$                        |
| Rejection region:     | $X^2 \geq X^2_{\alpha, k-1}$ ,  | where $k = 5$ .  |



The results are listed in the following table:

**Table 19: Contingency tables for question 31- 39 with calculated chi-squared values**

		total # of responses					Chi-square stat:	$X^2_{(.05, 4)}$	Reject Null?	$X^2_{(.1, 4)}$	Reject Null?	P Value
		1	2	3	4	5						
Question 31:	Low Focus	1	7	15	6	1	2.525	9.49	N	7.78	N	
	High Focus	0	8	17	3	2						
Question 32:	Low Focus	1	6	7	7	9	3.183	9.49	N	7.78	N	0.528
	High Focus	4	3	8	8	7						
Question 33:	Low Focus	8	13	9	0	0	38.727	9.49	Y	7.78	Y	0
	High Focus	0	0	13	9	8						
Question 34:	Low Focus	4	13	6	5	2	11.607	9.49	Y	7.78	Y	0.021
	High Focus	0	6	6	11	7						
Question 35:	Low Focus	1	11	8	8	2	7.255	9.49	N	7.78	N	
	High Focus	0	4	14	7	5						
Question 36:	Low Focus	1	5	12	8	4	3.397	9.49	N	7.78	N	0.494
	High Focus	1	4	9	6	10						
Question 37:	Low Focus	5	6	6	10	3	5.662	9.49	N	7.78	N	0.226
	High Focus	2	5	8	6	9						
Question 38:	Low Focus	5	6	5	12	2	9.785	9.49	Y	7.78	Y	0.044
	High Focus	1	5	11	6	7						
Question 39:	Low Focus	3	8	5	12	2	9.046	9.49	N	7.78	Y	0.06
	High Focus	0	6	10	7	7						

The questions in which the null hypothesis was rejected at the  $\alpha=.10$  level of significance are:

**Question 33:** Many employees are involved in environmental improvement.

**Question 34:** Our managers are too busy with day-to-day responsibilities to spend time on long-term environmental improvement projects.

**Question 38:** An adequate amount of training in environmental awareness is provided to hourly/direct labor employees within our plant.

**Question 39:** An adequate amount of training in environmental awareness is provided to managers and supervisors within our plant.

The questions in which the null hypothesis was not rejected at the  $\alpha=.10$  level of significance are:

- Question 31:** Approval and funding for environmental improvements is easy to acquire.
- Question 32:** We have dedicated environmental positions assigned in the company.
- Question 35:** Direct labor plays an important role in environmental improvement.
- Question 36:** Environmental responsibility is valued highly in the company culture.
- Question 37:** Environmental goals are clearly communicated to all plant personnel.

### 8.3.2 Creating and testing the “Hypothesis 3 score”

Again, as in the testing of hypotheses 1 and 2, a “Hypothesis 3 Score” (H3S) was calculated for each respondent by summing their selected answers for questions #31-39, dividing that sum by a max sum of 45, and multiplying that number by 100 to obtain a percentage (Again, based on the way some of the questions were structured, some of the scores needed to be “reversed” to create an accurate H3S). The scores were then arranged in a contingency table that tabulated the total number of scores above and below the median score of 64.44 for both the High Focus and Low Focus groups (the respondents who scored exactly the median score of 64.44 were omitted). This contingency table is shown below:

**Table 20: H3S contingency table**

<b>Hypothesis 3</b>	<b>Below H3S Median</b>	<b>Above H3S Median</b>
High Focus	13	15
Low Focus	16	12

Once again, a chi square test was performed where:

- Null Hypothesis:  $H_0$ : The H3S scores are independent to the degree of focus.
- Alternate Hypothesis:  $H_a$ : The H2S scores are not independent to the degree of focus.
- Test statistic:  $X^2 = \sum_{\text{all cells}} (\text{Observed} - \text{Expected})^2 / \text{Expected}$
- Rejection region:  $X^2 \geq X^2_{\alpha, k-1}$ , where  $k = 2$ .

The results are as follows:

**Table 21: Calculated Chi-squared value for H3S**

Hypothesis 3	Below H3S Median	Above H3S Median	Chi-square stat:	$X^2_{(.05, 1)}$	Reject Null?	$X^2_{(.1, 1)}$	Reject Null?	P Value
High Focus	13	15	0.644	3.843	N	2.706	N	0.422
Low Focus	16	12						

At  $X^2 = 0.644$ , we cannot reject the null hypothesis at either the .05 and .10 levels of significance and conclude that the H3S scores are independent to the degree of focus. In other words, it can be concluded that there is no significant difference in the H3S scores between the High Focus and Low Focus groups at either the 0.05 and 0.01 level.

#### 8.4.3. Conclusions on Hypothesis 3

In summary, 4 of the 9 individual survey questions for Hypothesis 3 were found to be not independent from the degree of focus. However, it could not be concluded that the H3S scores were not independent to the degree of focus. Based on this information, I would conclude that there is no significant statistical evidence to support Hypothesis 3. In other words, there is no significant evidence to believe to that the focused factory will be more likely to create and assign appropriate environmental positions, job duties, and responsibilities than the traditional factory. Further analysis for Hypothesis 3 is discussed in the section 9.

## 9. Final Results/Conclusions

Like many statistical experiments, the analysis generated a “mixed bag” of results. In summary, there was reasonable statistical evidence to support Hypothesis 1, but there wasn’t significant statistical evidence to support Hypotheses 2 or 3. However, the survey data can be further scrutinized to help explain why the data came out the way it did.

### 9.1 Further Degree of focus Analysis

Because the survey respondents indicated the number of employees working in their plant, as well as described the product they manufactured, this information could be paired with the individual degree of focus scores to see if any correlation exists. The following table lists the types of industries and range of employees for the respondents of both the high and low focus groups:

**Table 22: Survey Respondent Degree of focus Information**

<b>Industries of ten lowest DFS scores</b>	<b>Industries of ten highest DFS scores</b>
Industrial pump manufacturer	Manufacturer of surgical needles
Machine tool manufacturer	Automotive
Glass and ceramic manufacturer	Sheet metal and machining
Automotive OEM supplier	Utility monitoring equipment
Production machine shop	Heavy-duty diesel manufacturer
Industrial Products	Automotive component supplier
Machine tool manufacturer	Telecommunications
Fluid control products and actuation systems	Injection molding
Non-contact metrology	Plastic injection molding
Aerospace	Medical products
<b>Number of employees</b>	<b>Number of employees</b>
25 -100: 6	25 -100: 5
101-500: 7	101-500: 12
501-1000: 6	501-1000: 2
1001-1500: 4	1001-1500: 2
1501+ : 4	1501+ : 13
Unknown: 3	Unknown: 6
<b>Average # of employees: 849.12</b>	<b>Average # of employees: 767.60</b>

There wasn't really any noticeable difference between the industry types of the ten highest DFS scores and ten lowest DFS scores. The industries, more or less, looked to be standard manufacturing types; no discernable differences could be determined by simply looking at these basic industry descriptions.

Looking at plant size, the low focus group had a larger average number of employees than the high focus group. The low focus group also had more plants with over 500 employees, whereas the high focus group had more plants with less than 500 employees. This makes sense as research on focus suggests companies tend to become less focused as they grow in size and scope (Hill, 1989).

## **9.2 Further Analysis on Hypothesis 1**

Looking at the individual survey questions for hypothesis 1, the study showed positive correlation between focus and 1) increased cost savings and 2) increased earning potential due to environmental efforts, 3) going beyond compliance issues to proactively seek further environmental improvements, 4) a business strategy that includes environmental goals and priorities, and 5) environmental improvements to improve the profitability of the plant.

However, the survey did not show any correlation between focus and reduction in waste, emissions, consumption in raw materials or energy; nor did it show any correlation between focus and emphasizing a well-defined set of environmental policies and procedures. The contradictions are interesting. How can companies perceive cost savings and increased earning potential due to environmental efforts, yet not perceive a reduction in consumption of raw materials, waste, energy, etc? Also, how can companies include environmental goals and priorities in their business strategy, as well as seek proactive environmental improvements, yet not have well-defined environmental policies and procedures? The most likely cause for the differing results between questions is the subjectivity of questions themselves. The use of the word "significant" in these questions (i.e., Our plant has experienced a significant reduction in waste and/or emission due to environmental efforts) probably had an impact on the results. It is probably hard for many respondents to determine what constitutes "significant" reductions in waste and/or

emissions. It is likely that respondents could easier determine “significant” cost savings due to environmental efforts, by simply looking at dollar amounts.

The industry description and employee size information could also be paired with the individual H1S scores to see if any correlation exists:

**Table 23: Survey Respondent Hypothesis 1 Score (H1S) Information**

RESPONSES BELOW H1S MEDIAN		RESPONSES ABOVE H1S MEDIAN	
# of employees	# of responses	# of employees	# of responses
25-100:	7	25-100:	2
101-500:	5	101-500:	11
501-1000:	5	501-1000:	1
1001 1500:	1	1001 1500:	3
1501+ :	1	1501+ :	7
Unknown:	6	Unknown:	4
Average # of employees: <b>559.16</b>		Average # of employees: <b>1195.04</b>	
<b>Industry type of lowest 5 scores</b>		<b>Industry type of highest 5 scores</b>	
Sheet metal & machining		Heavy duty diesel manufacturer	
Diffraction grating manufacturer		Powdered metal component producer	
Electromagnetic components		Manufacturer of fine haircare products	
Tranducers & transmitters		Glass and ceramic products	
Machine tool manufacturer		Printer manufacturer	

The data showed that the plants above the median H1S score had a much larger average employee size than then the plants with H1S scores below the median. This can possibly suggest that larger plants are more environmentally successful than smaller plants. This would make sense as larger companies probably have more resources available to develop and pursue environmental strategies. For additional analysis, the following table further compares employee size with H1S and focus:

**Table 24: Survey respondent Hypothesis 1 Score (H1S) information**

LOW FOCUS BELOW H1S MEDIAN		LOW FOCUS ABOVE H1S MEDIAN	
# of employees	# of responses	# of employees	# of responses
25-100:	4	25-100:	1
101-500:	3	101-500:	3
501-1000:	5	501-1000:	1
1001 - 1500:	1	1001 - 1500:	0
1501+ :	0	1501+ :	4
Unknown:	5	Unknown:	0
Average # of employees: 534.23		Average # of employees: 1477.22	

HIGH FOCUS BELOW H1S MEDIAN		HIGH FOCUS ABOVE H1S MEDIAN	
# of employees	# of responses	# of employees	# of responses
25-100:	3	25-100:	1
101-500:	2	101-500:	9
501-1000:	0	501-1000:	0
1001 - 1500:	0	1001 - 1500:	3
1501+ :	1	1501+ :	3
Unknown:	1	Unknown:	4
Average # of employees: 613.17		Average # of employees: 1036.31	

Nothing significant could be determined from this breakdown.

### **9.3 Further Analysis on Hypothesis 2 and Hypothesis 3**

The study didn't show any significant evidence that focused factories will implement more effective environmental strategies than the traditional factory (Hypothesis 2), or that they will be more likely to create and assign appropriate environmental positions, job duties, and responsibilities (Hypothesis 3). However, this doesn't necessarily mean Hypotheses 2 and 3 are not true. Simply, the data from the study didn't adequately support these theories.

Because Hypotheses 2 and 3 look for specific environmental strategies and infrastructure characteristics, it's quite possible that a major reason for the "lack of results" for Hypotheses 2 and 3 is that companies simply aren't doing enough environmentally. Looking at the questions for hypotheses 2 and 3 that were found to be independent to focus, it would appear that companies aren't easily acquiring approval and funding for environmental improvements (question 31), don't have dedicated environmental positions assigned within the company (question 32), and are not using environmental "best practices" such as LCA, using recycled materials, EMS, environmental benchmarking, etc (questions 25 –29). Advanced environmental strategies such as LCA, and EMS have yet to become common practices in American industry, so it's unlikely that these questions would generate a lot of positive responses. Also, most small companies probably simply don't have enough financial resources to allocate to environmental improvements.

Hypothesis 2 did show positive correlation between focus and bringing environmental considerations into the early stages product development (question 30). Focus has a lot to do with improving and better utilizing a company's infrastructure. Based on this data, it is possible that focus can help better utilize one's resources so they can allocate more time to environmental improvements. There were also some positive results shown in Hypothesis 3, which centers on company infrastructure. The study showed positive correlation between focus and employee and management involvement in environmental improvement (questions 33 and 34), and adequate amount of training in environmental awareness (questions 38 and 39).



The following tables again break down plant size and industry among Hypothesis 2 and 3 scores. Again, the plants that scored above the H2S and H3S medians had a larger average employee size than the plants that scored below the medians:

**Table 25: Survey Respondent Hypothesis 2 Score (H2S) Information**

RESPONSES BELOW H2S MEDIAN		RESPONSES ABOVE H2S MEDIAN	
# of employees	# of responses	# of employees	# of responses
25-100:	6	25-100:	2
101-500:	6	101-500:	11
501-1000:	3	501-1000:	2
1001 - 1500:	1	1001 - 1500:	4
1501+ :	3	1501+ :	5
Unknown:	5	Unknown:	7
Average # of employees: <b>584.38</b>		Average # of employees: <b>1111.13</b>	
<b>Industry type of lowest 5 scores</b>		<b>Industry type of highest 5 scores</b>	
Sheet metal & machining		Manufacturer of fine hair care products	
Diffraction grating manufacturer		Automotive	
Electromagnetic components		Powdered metal component producer	
Transducers & transmitters		Heavy duty diesel manufacturer	
Industrial pump manufacturer		Imaging products	

**Table 26: Survey Respondent Hypothesis 3 Score (H3S) Information**

RESPONSES BELOW H3S MEDIAN		RESPONSES ABOVE H3S MEDIAN	
# of employees	# of responses	# of employees	# of responses
25-100:	6	25-100:	2
101-500:	6	101-500:	11
501-1000:	3	501-1000:	2
1001 - 1500:	1	1001 - 1500:	4
1501+ :	3	1501+ :	5
Unknown:	5	Unknown:	7
Average # of employees: <b>773.23</b>		Average # of employees: <b>984.83</b>	
<b>Industry type of lowest 5 scores</b>		<b>Industry type of highest 5 scores</b>	
Optical fiber cable		Powdered Metal Component Producer	
Electromagnetic Components		Automotive	
Machine tool manufacturer		Manufacturer of fine haircare products	
Transducers and transmitters		Heavy Duty Diesel Manufacturer	
Diffraction grating manufacturer		Copier/Printer Manufacturer	

## 9.4 Follow-up Questions with Companies

An interesting statistic from the survey is that 23 of the 30 companies that generated a H1S score above the median, also generated both H2S and HS3 scores above the median. The other seven respondents scored above the H1S median, and below the median for either H2S or H3S. Six of these seven respondents were actually in the high focus group, and therefore played a significant altering the independence testing results.

An attempt was made to re-contact these companies with some follow up questions in order to gain some further insight on why they scored better on the hypothesis 1 questions than on questions for hypotheses 2 and 3. One of these companies responded that was in the high focus groups and produced various metal fasteners and materials. The respondent indicated that environmental issues were valued highly within the company and that the company had significantly reduced waste, emissions, and consumption of raw materials through environmental improvements. However, the respondent noted that this was mainly due to process changes, specifically using more energy efficient machinery that produces less waste and emissions. These improvements had more to do with the machines and processes rather than the employees. The respondent noted that little is done to involve the employees, themselves, in proactive environmental progress, and/or environmental awareness.

This follow up information helps indicate why this company scored better on the questions for hypothesis 1 than for hypotheses 2 and 3. Hypothesis 1 consisted of questions that assess the success of environmental improvements (reduction in waste, emissions, costs, etc), where this company scored well in these areas due to various process changes. However, hypotheses 2 and 3 asked questions regarding more specific environmental strategies and infrastructure changes, where this company generally was not too involved in.

Follow up information was also gathered from another company that was placed in the high focus group, but scored low on all three hypotheses questions. In regards to focus, the company indicated that it only produced a few different types of products, and had only two different product lines. The company noted quality is predominately emphasized over any other competitive priority. The respondent indicated the plant had a clear business strategy, and it does not change often. Each discrete process has a cell and

a given product flows from cell-to-cell in a specific order. In addition, the respondent stated that the floor workers aren't really involved in any of the decision-making process, but they are encouraged to speak up if they have concerns about a given issue. Also, the company has been implementing various "continuous improvement" methods such as Six Sigma and Lean, and the renewed emphasis on quality and Lean has improved morale and given the operators a renewed vigor for improvement.

Regarding environmental improvement, the respondent stated that, in terms of product design, functionality and cost are the primary drivers of design and that environmental factors fall pretty far down on the priority list. However, the only product they deal with is electrical components, which have little potentially harmful effects to the environment. On the other hand, the respondent indicated that one of the primary drivers in product design is efficiency: doing the same job with less fuel. Therefore, although they are motivated by factors other than the environment, the company's motivating factors are not counter-productive to environmental design. In addition, the company has only one person on-site who is a designated EHS (environmental health and safety) representative, but it is far from that person's only duties, and environmental issues usually fall somewhere down the list of priorities and only come up when needed (like for an emergency or training).

Although this company gave some good indicators of focus, its statements on environmental issues emphasize some common themes for lack of environmental development. Clearly, this company does not specifically integrate environmental issues into its business strategy, nor place environmental development high on its priority list (i.e., the EHS worker only responds to environmental issues when needed). It's not unreasonable to believe these problems can found among many other manufacturing plants. However, the fact that the respondent's primary driver of design efficiency ultimately leads to less fuel consumption, highlights the need for companies to view environmental issues in terms of creating business value. Most companies need to equate environmental efficiency with increased cost savings and/or profits to be motivated to make strides in this area.

## **9.5 Room for Error**

There is room for error in this experiment including: unqualified personnel taking the survey, misreading or misinterpreting the questions, and not taking enough time to accurately answer the questions. Because the primary experimental tool was a survey, the data can be expected to be subjective and may not fully represent the actual characteristics of the plant. It is possible that companies perceive themselves as more environmentally active than they really are, or that companies think they are making environmental issues a priority, when, in fact, they really aren't. Obviously, further in-depth research is needed in the area.

However, survey data is not intended to be completely "concrete". A survey was chosen as the primary experimental method for its ability to capture information from a wide variety of plants with different manufacturing styles and organizational structures. It is designed to capture a reasonable "snap shot" of the population it is seeking to measure, and I think the survey succeeded on doing that.

## **9.6 Final Thoughts and Recommendations for Future Research**

In conclusion, the study generated mixed results. The data analysis did show evidence of positive correlation between focus and environmental improvement for some measures, but also generated insignificant evidence of correlation for other measures. The study was a successful initial exploration into the subject of environmental improvement with respect to focus, but further research is needed to adequately link focus to environmental improvement.

Having more responses could have made a difference to the results of the survey. One encouraging measure is by looking at the average scores of the survey:

**Table 27: Average survey scores**

	Low Focus	High Focus
<b>Average DFS</b>	<b>55.52</b>	<b>70.24</b>
<b>Average h1s</b>	<b>55.40</b>	<b>67.33</b>
<b>Average h2s</b>	<b>60.78</b>	<b>68.22</b>
<b>Average h3s</b>	<b>60.52</b>	<b>68.00</b>
<b>Hypothesis 1</b>		
Question 15	2.53	3.20
Question 16	3.10	3.50
Question 17	2.77	3.20
Question 18	2.53	2.87
Question 19	2.83	3.27
Question 20	2.50	3.30
Question 21	2.90	3.67
Question 22	2.70	3.63
Question 23	2.67	3.40
Question 24	3.17	3.63
<b>Hypothesis 2</b>		
Question 25	2.70	3.07
Question 26	3.30	3.30
Question 27	3.10	3.30
Question 28	3.57	4.13
Question 29	2.83	3.27
Question 30	2.73	3.40
<b>Hypothesis 3</b>		
Question 31	2.97	2.97
Question 32	3.57	3.37
Question 33	2.77	3.10
Question 34	2.60	3.63
Question 35	2.97	3.43
Question 36	3.30	3.67
Question 37	3.00	3.50
Question 38	3.00	3.43
Question 39	3.07	3.50

Looking at this table, the respondents in the High Focus group averaged better scores on every single question, except for question 32. The average H1S, H2S, and H3S scores were also much higher for the High Focus group than then the Low Focus group. Even though the total of 60 respondents for the survey is perfectly valid for statistical research, obtaining some more responses may have altered the results.

Focused factories and advanced environmental strategies are two very complex concepts that integrate a large number of internal and external issues. Obtaining a true

“degree of focus” for a company, in itself, is a very difficult thing to measure, so a survey cannot be expected to give us a completely accurate portrayal of reality. In addition, expansive environmental strategies are still a relatively uncommon practice in American industry. Most business survey respondents, especially small sized companies, probably don’t place a high priority on proactive environmental issues. More detailed case studies would be required to further analyze environmental improvement with respect to focus.

Focus can ultimately be a key in establishing long-lasting environmental and sustainable strategies for companies. Using environmental improvements as a business strategy to create business value is critical. In other words, for environmental solutions to become commonplace in the mindset of US manufacturers, companies need to equate environmental issues with saving and/or making money.

There were many initial ideas generated in section 5 that did not get to be tested in this study. Many of these would make excellent topics for future research. Especially of interest would be proposition 5: the focused factory will be more likely to develop proper, specific environmental strategies for each focused unit, and their corresponding competitive priorities and proposition 6: in a focused factory, the environmental design changes for a particular product or process will be less likely to contend with other conflicting products or processes.

In respect to proposition 5, a very interesting test would be to determine if different competitive priorities require different environmental strategies. As Rothenberg *et al.* (1992) argued, perhaps each factory needs to develop its own environmental strategy that is best fit to the specific external and internal conditions that the factory faces. Does producing a high quality product impact the environmental choices a factory would make differently than a company producing a low cost, low quality product? If so, focused factories may provide the foundation for proper environmental strategies, because each focused unit would have a specific, consistent competitive priority that the entire unit revolves around. Examining this theory would most likely require extensive case study research, but would provide valuable insight into establishing sound environmental strategies that are compatible with a company’s core business strategies.

In addition, proposition 6 would be an interesting topic for future research. Theoretically, focus factories arrange the plant into separate “units” that concentrate on a

limited set of products and processes. Therefore, in environmental terms, the focused units will only need to concentrate on improving the environmental performance of a limited number of products or processes. This may lead to easier implementation of effective environmental strategies as the environmental design changes for a particular product or process will be less likely to contend with other conflicting products or processes in a focused factory. Further examining this theory could also help companies gain insight into the linkages between environmental strategy and business strategy.

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# Appendix A: The Survey

Company name:

Company description:

Number of employees:

How well do you agree with the following statements regarding your company?

1 = Completely Disagree

2 = Somewhat Disagree

3 = Neutral

4 = Somewhat Agree

5 = Completely Agree

	Completely Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Completely Agree
1. Varying customer orders and demands disrupt the flow of our manufacturing processes.	1	2	3	4	5
2. Our company's level of bureaucracy hinders our ability to implement process and/or product improvements.	1	2	3	4	5
3. Certain competitive requirements (ex. Low cost, high quality, fast delivery, etc.) are clearly prioritized for each product we make.	1	2	3	4	5
4. We will accept a new customer order that requires significant modifications to our manufacturing processes.	1	2	3	4	5
5. Our plant tries to address a large number of customer demands.	1	2	3	4	5
6. Our business strategy changes often.	1	2	3	4	5
7. We rely on input from multifunctional teams (i.e. Engineering / Marketing / Purchasing / Operations, etc.) in plant decision making.	1	2	3	4	5
8. We place products with similar manufacturing characteristics and/or volumes into separate cells or areas.	1	2	3	4	5
9. Our direct labor force is given more responsibility than in traditional companies.	1	2	3	4	5
10. Each employee is well aware of our company's business goals and objectives.	1	2	3	4	5
11. Our functional departments routinely co-ordinate their activities.	1	2	3	4	5
12. Our business strategy clearly lays out a limited set of priorities for manufacturing.	1	2	3	4	5
13. Our plant relies on an extensive amount of traditional production supervision.	1	2	3	4	5
14. Our plant has to expedite product frequently.	1	2	3	4	5
15. Our plant has experienced significant cost savings due to environmental efforts.	1	2	3	4	5
16. Our plant has experienced a significant reduction in waste and/ or emissions due to environmental efforts.	1	2	3	4	5
17. Our plant has significantly reduced energy usage through environmental improvements.	1	2	3	4	5

18. Our plant has significantly reduced the consumption of raw materials due to environmental improvements.	1	2	3	4	5
19. Our plant has improved its image due to environmental efforts.	1	2	3	4	5
20. Our plant has increased its earning potential due to environmental efforts.	1	2	3	4	5
21. Our plant goes beyond compliance issues to proactively seek further environmental improvement.	1	2	3	4	5
22. Our business strategy includes environmental goals and priorities.	1	2	3	4	5
23. Our plant makes environmental improvements to improve the profitability of the plant.	1	2	3	4	5
24. Environmental responsibility is emphasized through a well defined set of environmental policies and procedures.	1	2	3	4	5
25. We perform life cycle analyses for our products as a part of our environmental efforts.	1	2	3	4	5
26. Our plant uses recycled parts and/or materials in our production process.	1	2	3	4	5
27. Our plant has an environmental management system (EMS) in place or is working to implement an EMS.	1	2	3	4	5
28. We have successfully replaced hazardous materials in our products and/or processes with more environmentally benign products.	1	2	3	4	5
29. Environmental practices, procedures, and systems within our plant are compared with best-in-class on a regular basis.	1	2	3	4	5
30. We bring environmental considerations into the early stages of product development.	1	2	3	4	5
31. Approval and funding for environmental improvements is easy to acquire.	1	2	3	4	5
32. We have dedicated environmental positions assigned in the company.	1	2	3	4	5
33. Many employees are involved in environmental improvement.	1	2	3	4	5
34. Our managers are too busy with day-to-day responsibilities to spend time on long-term environmental improvement projects.	1	2	3	4	5
35. Direct labor plays an important role in environmental improvement.	1	2	3	4	5
36. Environmental responsibility is valued highly in the company culture.	1	2	3	4	5
37. Environmental goals are clearly communicated to all plant personnel.	1	2	3	4	5
38. An adequate amount of training in environmental awareness is provided to hourly/direct labor employees within our plant.	1	2	3	4	5
39. An adequate amount of training in environmental awareness is provided to managers and supervisors within our plant.	1	2	3	4	5

## Appendix B: Minitab output for Chi-Squared Analysis

### Question 15:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts

Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	4	13	8	3	2	30
	3.00	8.00	11.50	5.00	2.50	
	0.333	3.125	1.065	0.800	0.100	
2	2	3	15	7	3	30
	3.00	8.00	11.50	5.00	2.50	
	0.333	3.125	1.065	0.800	0.100	
Total	6	16	23	10	5	60

Chi-Sq = 10.847, DF = 4, P-Value = 0.028

4 cells with expected counts less than 5.

### Question 16:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts

Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	2	8	8	9	3	30
	2.00	5.00	9.50	9.00	4.50	
	0.000	1.800	0.237	0.000	0.500	
2	2	2	11	9	6	30
	2.00	5.00	9.50	9.00	4.50	
	0.000	1.800	0.237	0.000	0.500	
Total	4	10	19	18	9	60

Chi-Sq = 5.074, DF = 4, P-Value = 0.280

4 cells with expected counts less than 5.

### Question 17:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts

Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	4	7	11	8	0	30
	3.50	5.50	11.50	7.00	2.50	
	0.071	0.409	0.022	0.143	2.500	

2	3	4	12	6	5	30
	3.50	5.50	11.50	7.00	2.50	
	0.071	0.409	0.022	0.143	2.500	
Total	7	11	23	14	5	60

Chi-Sq = 6.290, DF = 4, P-Value = 0.178  
4 cells with expected counts less than 5.

### Question 18:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts  
Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	6	10	8	4	2	30
	4.50	9.00	9.50	5.00	2.00	
	0.500	0.111	0.237	0.200	0.000	
2	3	8	11	6	2	30
	4.50	9.00	9.50	5.00	2.00	
	0.500	0.111	0.237	0.200	0.000	
Total	9	18	19	10	4	60

Chi-Sq = 2.096, DF = 4, P-Value = 0.718  
4 cells with expected counts less than 5.

### Question 19:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts  
Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	4	8	10	5	3	30
	3.00	6.00	10.50	7.50	3.00	
	0.333	0.667	0.024	0.833	0.000	
2	2	4	11	10	3	30
	3.00	6.00	10.50	7.50	3.00	
	0.333	0.667	0.024	0.833	0.000	
Total	6	12	21	15	6	60

Chi-Sq = 3.714, DF = 4, P-Value = 0.446  
4 cells with expected counts less than 5

### Question 20:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts  
Chi-Square contributions are printed below expected counts



	C2	C3	C4	C5	C6	Total
1	5	12	8	3	2	30
	3.50	7.50	10.50	5.50	3.00	
	0.643	2.700	0.595	1.136	0.333	
2	2	3	13	8	4	30
	3.50	7.50	10.50	5.50	3.00	
	0.643	2.700	0.595	1.136	0.333	
Total	7	15	21	11	6	60

Chi-Sq = 10.816, DF = 4, P-Value = 0.029  
 4 cells with expected counts less than 5.

## Question 21:

### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts  
 Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	4	8	6	11	1	30
	2.00	5.50	8.00	11.00	3.50	
	2.000	1.136	0.500	0.000	1.786	
2	0	3	10	11	6	30
	2.00	5.50	8.00	11.00	3.50	
	2.000	1.136	0.500	0.000	1.786	
Total	4	11	16	22	7	60

Chi-Sq = 10.844, DF = 4, P-Value = 0.028  
 4 cells with expected counts less than 5.

## Question 22:

### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts  
 Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	6	7	10	4	3	30
	3.50	5.00	10.50	5.00	6.00	
	1.786	0.800	0.024	0.200	1.500	
2	1	3	11	6	9	30
	3.50	5.00	10.50	5.00	6.00	
	1.786	0.800	0.024	0.200	1.500	
Total	7	10	21	10	12	60

Chi-Sq = 8.619, DF = 4, P-Value = 0.071  
 2 cells with expected counts less than 5.

### Question 23:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts

Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	4	11	8	5	2	30
	2.50	7.50	10.00	6.50	3.50	
	0.900	1.633	0.400	0.346	0.643	
2	1	4	12	8	5	30
	2.50	7.50	10.00	6.50	3.50	
	0.900	1.633	0.400	0.346	0.643	
Total	5	15	20	13	7	60

Chi-Sq = 7.845, DF = 4, P-Value = 0.097

4 cells with expected counts less than 5.

### Question 24:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts

Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	3	8	5	9	5	30
	2.50	5.00	7.00	9.00	6.50	
	0.100	1.800	0.571	0.000	0.346	
2	2	2	9	9	8	30
	2.50	5.00	7.00	9.00	6.50	
	0.100	1.800	0.571	0.000	0.346	
Total	5	10	14	18	13	60

Chi-Sq = 5.635, DF = 4, P-Value = 0.228

2 cells with expected counts less than 5.

### Question 25:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts

Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	7	6	8	7	2	30
	5.00	5.50	9.50	8.00	2.00	
	0.800	0.045	0.237	0.125	0.000	
2	3	5	11	9	2	30
	5.00	5.50	9.50	8.00	2.00	

	0.800	0.045	0.237	0.125	0.000	
Total	10	11	19	16	4	60

Chi-Sq = 2.415, DF = 4, P-Value = 0.660  
 2 cells with expected counts less than 5.

### Question 26:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts  
 Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	3	7	3	12	5	30
	3.50	6.50	3.50	10.50	6.00	
	0.071	0.038	0.071	0.214	0.167	
2	4	6	4	9	7	30
	3.50	6.50	3.50	10.50	6.00	
	0.071	0.038	0.071	0.214	0.167	
Total	7	13	7	21	12	60

Chi-Sq = 1.125, DF = 4, P-Value = 0.890  
 4 cells with expected counts less than 5.

### Question 27:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts  
 Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	7	4	5	7	7	30
	6.00	4.00	6.00	6.00	8.00	
	0.167	0.000	0.167	0.167	0.125	
2	5	4	7	5	9	30
	6.00	4.00	6.00	6.00	8.00	
	0.167	0.000	0.167	0.167	0.125	
Total	12	8	12	12	16	60

Chi-Sq = 1.250, DF = 4, P-Value = 0.870  
 2 cells with expected counts less than 5.

### Question 28:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts  
 Chi-Square contributions are printed below expected counts

C2	C3	C4	C5	C6	Total
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1	1	4	8	11	6	30
	1.00	3.00	5.50	10.50	10.00	
	0.000	0.333	1.136	0.024	1.600	
2	1	2	3	10	14	30
	1.00	3.00	5.50	10.50	10.00	
	0.000	0.333	1.136	0.024	1.600	
Total	2	6	11	21	20	60

Chi-Sq = 6.187, DF = 4, P-Value = 0.186  
 4 cells with expected counts less than 5.

## Question 29:

### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts  
 Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	6	3	4	4	3	20
	3.60	2.40	6.40	4.40	3.20	
	1.600	0.150	0.900	0.036	0.013	
2	3	3	12	7	5	30
	5.40	3.60	9.60	6.60	4.80	
	1.067	0.100	0.600	0.024	0.008	
Total	9	6	16	11	8	50

Chi-Sq = 4.498, DF = 4, P-Value = 0.343  
 6 cells with expected counts less than 5.

## Question 30:

### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts  
 Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	6	4	12	8	0	30
	3.50	3.50	13.00	7.50	2.50	
	1.786	0.071	0.077	0.033	2.500	
2	1	3	14	7	5	30
	3.50	3.50	13.00	7.50	2.50	
	1.786	0.071	0.077	0.033	2.500	
Total	7	7	26	15	5	60

Chi-Sq = 8.935, DF = 4, P-Value = 0.063  
 6 cells with expected counts less than 5.

### Question 31:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts

Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	1	7	15	6	1	30
	0.50	7.50	16.00	4.50	1.50	
	0.500	0.033	0.063	0.500	0.167	
2	0	8	17	3	2	30
	0.50	7.50	16.00	4.50	1.50	
	0.500	0.033	0.063	0.500	0.167	
Total	1	15	32	9	3	60

Chi-Sq = 2.525, DF = 4

WARNING: 2 cells with expected counts less than 1. Chi-Square approximation probably invalid.

6 cells with expected counts less than 5.

### Question 32:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts

Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	1	6	7	7	9	30
	2.50	4.50	7.50	7.50	8.00	
	0.900	0.500	0.033	0.033	0.125	
2	4	3	8	8	7	30
	2.50	4.50	7.50	7.50	8.00	
	0.900	0.500	0.033	0.033	0.125	
Total	5	9	15	15	16	60

Chi-Sq = 3.183, DF = 4, P-Value = 0.528

4 cells with expected counts less than 5.

### Question 33:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts

Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	8	13	9	0	0	30
	4.00	6.50	11.00	4.50	4.00	
	4.000	6.500	0.364	4.500	4.000	

2	0	0	13	9	8	30
	4.00	6.50	11.00	4.50	4.00	
	4.000	6.500	0.364	4.500	4.000	
Total	8	13	22	9	8	60

Chi-Sq = 38.727, DF = 4, P-Value = 0.000  
6 cells with expected counts less than 5.

### Question 34:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts  
Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	4	13	6	5	2	30
	2.00	9.50	6.00	8.00	4.50	
	2.000	1.289	0.000	1.125	1.389	
2	0	6	6	11	7	30
	2.00	9.50	6.00	8.00	4.50	
	2.000	1.289	0.000	1.125	1.389	
Total	4	19	12	16	9	60

Chi-Sq = 11.607, DF = 4, P-Value = 0.021  
4 cells with expected counts less than 5.

### Question 35:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts  
Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	1	11	8	8	2	30
	0.50	7.50	11.00	7.50	3.50	
	0.500	1.633	0.818	0.033	0.643	
2	0	4	14	7	5	30
	0.50	7.50	11.00	7.50	3.50	
	0.500	1.633	0.818	0.033	0.643	
Total	1	15	22	15	7	60

Chi-Sq = 7.255, DF = 4  
WARNING: 2 cells with expected counts less than 1. Chi-Square approximation probably invalid.  
4 cells with expected counts less than 5.

### Question 36:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts

Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	1	5	12	8	4	30
	1.00	4.50	10.50	7.00	7.00	
	0.000	0.056	0.214	0.143	1.286	
2	1	4	9	6	10	30
	1.00	4.50	10.50	7.00	7.00	
	0.000	0.056	0.214	0.143	1.286	
Total	2	9	21	14	14	60

Chi-Sq = 3.397, DF = 4, P-Value = 0.494

4 cells with expected counts less than 5

### Question 37:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts

Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	5	6	6	10	3	30
	3.50	5.50	7.00	8.00	6.00	
	0.643	0.045	0.143	0.500	1.500	
2	2	5	8	6	9	30
	3.50	5.50	7.00	8.00	6.00	
	0.643	0.045	0.143	0.500	1.500	
Total	7	11	14	16	12	60

Chi-Sq = 5.662, DF = 4, P-Value = 0.226

2 cells with expected counts less than 5.

### Question 38:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts

Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	5	6	5	12	2	30
	3.00	5.50	8.00	9.00	4.50	
	1.333	0.045	1.125	1.000	1.389	
2	1	5	11	6	7	30
	3.00	5.50	8.00	9.00	4.50	

	1.333	0.045	1.125	1.000	1.389	
Total	6	11	16	18	9	60

Chi-Sq = 9.785, DF = 4, P-Value = 0.044  
 4 cells with expected counts less than 5.

### Question 39:

#### Chi-Square Test: C2, C3, C4, C5, C6

Expected counts are printed below observed counts  
 Chi-Square contributions are printed below expected counts

	C2	C3	C4	C5	C6	Total
1	3	8	5	12	2	30
	1.50	7.00	7.50	9.50	4.50	
	1.500	0.143	0.833	0.658	1.389	
2	0	6	10	7	7	30
	1.50	7.00	7.50	9.50	4.50	
	1.500	0.143	0.833	0.658	1.389	
Total	3	14	15	19	9	60

Chi-Sq = 9.046, DF = 4, P-Value = 0.060  
 4 cells with expected counts less than 5.